PROCEEDINGS
THE INSTITUTION OF CIVIL ENGINEERS

PART I
JULY 1953

ORDINARY MEETING

17 February, 1953

HENRY FRANCIS CRONIN, C.B.E., M.C., B.Sc.(Eng.), President, in the Chair

The President informed the Meeting, with great regret, of the death of Sir Leopold Halliday Savile, K.C.B., Past-President of the Institution. A resolution of condolence had been passed by the Council and conveyed to the members of Sir Leopold's family.

The Council reported that they had recently transferred to the class of

Members

CLARK, JAMES ALEXANDER MUIRHEAD, B.Sc. (*Glasgow*).
CLENDON, THOMAS VIVIAN.
CORMIE, *Lt.-Col.* WILLIAM MURRAY, O.B.E., B.Sc. (*Glasgow*).
HAVILAND, JOHN HAVILAND, B.Sc. (*Witwatersrand*).
JACKSON, LEONARD, B.Eng. (*Sheffield*).
LIPSHITZ, MARCUS, B.Sc. (*Cape Town*).
LOVELAND, ALEC JOHN, B.Sc. (Eng.) (*London*).
MARCHANT, PHILIP VICTOR.
NEILL, JOSEPH MCFERRAN, M.Sc. (*Belfast*).
VAUGHAN-WILLIAMS, JAMES, D.S.O., T.D.
YOUNG, JAMES.

and had admitted as

Graduates

ALAM, AFTAB, B.Sc. (*Punjab*), Stud. I.C.E.
ALDWINCKLE, CLIFFORD HENRY, B.Sc. (*Nottingham*).
ALLEN, JOHN WILLIAM, B.Sc. (Eng.) (*London*), Stud.I.C.E.
ALLISON, GORDON FRANCIS, Stud.I.C.E.
AMOS, EDWARD BARRYMORE, Stud.I.C.E.
ANDERSON, GERALD ANTHONY, B.Sc. (*Durham*).
ANDERSON, KENNETH MORGAN, B.Sc. (*St Andrews*).

Arber, Alan William, Stud.I.C.E.
Auger, George Charles Boyd, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Bankart, Patrick Gordon, B.Sc. (Eng.) (*London*).
Bannister, David Humphrey, Stud. I.C.E.
Barrow, Arthur, B.Sc. (*Manchester*).
Bennett, Vivian Wilfrid.
Binsted, Donald Scott, B.Sc. (Eng.) (*London*).
Bose, Sailendra Nath, B.E. (*Calcutta*), Stud.I.C.E.
Botwood, Percy Morgan, Stud.I.C.E.
Brook, Keith Malcolm, B.Sc. (*Leeds*), Stud.I.C.E.
Brown, Andrew Keith Murray, Stud. I.C.E.
Brunt, Hugh Michael, B.Sc. (*Wales*).
Burslem, John Austin, Stud.I.C.E.
Butler, Geoffrey Reginald Charles, B.Sc. (Eng.) (*London*).
Casinader, Ranjitan Justin Tambimuttu, B.A. (*Cantab.*).
Chapman, Thomas Grandin, B.Sc. (*Leeds*), Stud.I.C.E.
Cheesbrough, Robert, B.Sc.Tech. (*Manchester*).
Clark, Jean-Pierre George.
Clarke, William Robert, B.Sc. (*Belfast*).
Clutterbuck, Peter Royston, Stud. I.C.E.
Coard, Charles Walton Richard Rumney.
Collins, Robert John, B.Sc.(Eng.) (*London*), Stud.I.C.E.
Colman, David Gerald, Stud.I.C.E.
Conway, John d'Arcy, B.Sc. (*Glasgow*), Stud.I.C.E.
Coon, Robert James, Stud.I.C.E.
Copley, Bryan, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Cox, Dennis Edward, B.Sc. (Eng.) (*London*).
Craig, Douglas Malcolm, B.Sc. (*St Andrews*), Stud.I.C.E.
Cross, Kenneth Ernest, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Cunnington, Frederick Peter, Stud. I.C.E.
Dalman, John Barry, Ph.D., B.Sc. (*Birmingham*).
Dapling, Edwin Thomas, Stud.I.C.E.
Davidson, Antony Edward, B.Sc. (Eng.) (*London*).
Davis, Alexander Percival, B.Sc. (Eng.) (*London*).
Dolan, John Alexander, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Dorton, Roger Anthony, B.Sc. (*Nottingham*), Stud.I.C.E.
Dzierzykraj-morawski, Kajetan Maria Jozef, B.Sc. (Eng.) (*London*).
Earnshaw, Frank, Stud.I.C.E.
Edwards, Arthur David, B.Sc. (Eng.) (*London*).
Evans, Richard Glyn, Stud.I.C.E.
Farmer, Murray McKissock, Stud. I.C.E.
Faure, Peter David, B.Sc. (*Cape Town*).
Fraser, John Molloy, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Freer, Charles Noel, Stud.I.C.E.
Fulcher, David Leonard, Stud.I.C.E.
Furney, Franks Oliver, B.A., B.A.I. (*Dublin*).
Gamse, Joel David Harold, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Graham, Robert Dickson, B.Sc. (*Edinburgh*), Stud.I.C.E.
Grainger, Ian Gerard, B.Sc. (*Durham*).
Green, John Alexander, B.Sc. (Eng.) (*London*).
Greenbank, Geoffrey Holmes, B.Eng. (*Liverpool*).
Greenland, Stanley William, Stud. I.C.E.
Greig, William James, B.Sc. (*Aberdeen*).
Griffin, John Wilton, B.A., B.A.I. (*Dublin*).
Griggs, Charles Anthony, B.Sc. (Eng.) (*London*).
Gunatilaka, Kalumin Harischandra Shummukaweera De Zoysa Wickramaratne.
Hamilton, Ian Fleming, B.Sc. (*Glasgow*), Stud.I.C.E.
Harris, George Johnstone Kerr, B.Sc. (*Glasgow*), Stud.I.C.E.
Hartshorne, Samuel Anthony Towers, Stud.I.C.E.
Henderson, Harry Westwood, Stud. I.C.E.
Heyworth, John Desmond, B.Sc.Tech. (*Manchester*), Stud.I.C.E.
Hill, John Alexander.
Hockin, David Lashbrook, Stud.I.C.E.
Hollington, Michael Robert, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Holmes, Malcolm, B.Sc. (*Leeds*), Stud. I.C.E.
Hood, Hugh Waddell, B.Sc. (*Glasgow*), Stud.I.C.E.
Howat, Daniel Russell, B.Sc. (*Glasgow*).
Hughes, John.
Humphrey, George Harold, B.Sc. Tech. (*Manchester*), Stud.I.C.E.
Hutton, Peter Desmond, B.Sc. (Eng.) (*London*).
Inglis, Alexander Baird, B.Eng. (*Liverpool*).

Ironside, Alasdair James, B.Sc. (*Glasgow*).
Jenkins, Eddie, Stud.I.C.E.
Jenkins, Kenneth, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Johnson, Edward Roland Noel, B.E. (*New Zealand*).
Jory, Peter, B.Sc. (*Bristol*).
Joshi, Aravinda Vithal, B.E. (*Poona*), Stud.I.C.E.
Kent, Alan Jackson, Stud.I.C.E.
Kershaw, Cyril Gordon, B.A. (*Cantab.*), Stud.I.C.E.
Key, David Edwin, B.Sc. (Eng.) (*London*).
Kingston, Richard, B.A., B.A.I. (*Dublin*).
Kingston, William Mervyn, B.A., B.A.I. (*Dublin*).
Kirby, Thomas Henry, Stud.I.C.E.
Laing, Morris Campbell, B.Sc. (*Edinburgh*).
Lang, Eric, Stud.I.C.E.
Last, John Derrick, B.Sc. (Eng.) (*London*).
Leaman, William John, B.Sc. (*Bristol*).
Le Masurier, Michael, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Littley, Frederick Bryan, B.Sc. (*Birmingham*), Stud.I.C.E.
Loadsman, Roy Vernon Charles.
Lydon, Francis Dominick, B.E. (*National*).
McDermott, Dermot Peter, B.E. (*National*), Stud.I.C.E.
McEwan, David, B.Sc. (*Glasgow*), Stud.I.C.E.
Mackay, Ewen Beaton.
McKinlay, George Cowan, B.Sc. (*Glasgow*).
Mackrell, Alexander George, B.Sc. (Eng.) (*London*).
McNamara, Robert Edward, M.A. (*Cantab.*).
McPherson, Robert Graham Neil, Stud.I.C.E.
MacSween, Norman, B.Sc. (*Glasgow*).
Mander, Reginald Frederick.
Martin, Jack Trevor, B.Sc.Tech. (*Manchester*).
Mead, Paul Frederick.
Miley, Norman, B.Sc. (*Belfast*).
Milligan, Victor, M.Sc. (*Belfast*), Stud.I.C.E.
Mitchell, James Gordon, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Morton, Brian Philip, M.A. (*Cantab.*).
Murdoch, Edward Ferguson, B.Sc. (*Glasgow*), Stud.I.C.E.
Murray, George Patrick Emslie, Stud.I.C.E.
Murrell, Alexander Campbell, Stud.I.C.E.
Nadin, Keith Stuart, Stud.I.C.E.
Nicholls, Roy Alan, B.Sc. (Eng.) (*London*).
Nicholson, Norman, B.A. (*Oxon.*).
Nisbett, David John, B.Sc. (Eng.) (*London*).
Nunan, Timothy Raymond, B.E. (*National*).
Orr, William Tannahill, B.A. (*Cantab.*), Stud.I.C.E.
Osborne, Harry Bray, B.Sc. (Eng.) (*London*).
Oulton, Harry Andrew, M.Eng. (*Liverpool*), Stud.I.C.E.
Pannett, Robin James, Stud.I.C.E.
Parkins, Ian Clark Norman Ward, B.Sc. (*St Andrews*), Stud.I.C.E.
Paterson, Dennis Robert, B.Sc. (*Bristol*).
Payne, Richard James, B.Sc. (Eng.) (*London*).
Pearson, James Leslie.
Peart, Gerald Ernest Walter, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Pineo, Roger Michael Bramley, B.Sc. (*South Africa*).
Porter, Arthur James, B.Sc.Tech. (*Manchester*), Stud.I.C.E.
Power, Samuel Robert Douglas, B.A., B.A.I. (*Dublin*).
Pretorius, Percival Johannes, B.Sc. (*Cape Town*), Stud.I.C.E.
Reaney, Michael Bernard, B.Sc. (*Belfast*).
Redshaw, Thomas Harry, B.Sc. (Eng.) (*London*).
Rendle, Philip John, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Riding, Christopher Rolleston, B.A. (*Cantab.*), Stud.I.C.E.
Robison, Walter Frederick.
Rodger, David Alexander, B.Sc. (*Glasgow*).
Ruse, Noel Anthony, Stud.I.C.E.
Russell, John Curran, B.Sc. (*St Andrews*).
Sanderson, Bryan Muir.
Sandiford, Eric Hunstone, B.Sc.Tech. (*Manchester*).
Saunders, James Edward.
Sayer, Kenneth Nisbet, B.Sc. (*Glasgow*).
Sayles, Colin, Stud.I.C.E.
Seaward, Dennis Roy, B.Sc. (*Manchester*), Stud.I.C.E.
Shaw, Laurence Sime, B.Sc. (*St Andrews*).
Shedden, James Auld, B.Sc. (*Glasgow*), Stud.I.C.E.
Shuker, Donald Edward, Stud.I.C.E.

Shuttleworth, Patrick Estill, B.Sc. (*Witwatersrand*).
Smith, John Victor Milford, Stud. I.C.E.
Smith, Raymond.
Springfield, John, B.Sc. (*Nottingham*), Stud.I.C.E.
Stalley, Peter Bernard.
Stapleton, Anthony John, B.A., B.A.I. (*Dublin*).
Stewardson, Peter Brown, B.Sc. (*Durham*).
Thomas, John Roland, B.Sc. (*Wales*), Stud.I.C.E.
Thompson, James Crawford, B.Sc. (*Belfast*).
Thomson, Angus James Orr, B.A. (*Cantab.*), Stud.I.C.E.
Trott, Dennis Hodgson, B.Sc. (Eng.) (*London*).
Tucker, Geoffrey Peter, Stud.I.C.E.
Turner, Peter Maurice, B.Sc. (Eng.) (*London*).
Turton, Eric Victor William, B.Eng. (*Liverpool*), Stud.I.C.E.
Utting, Stanley Edward, Stud.I.C.E.
Walsh, Malachy, B.E. (*National*).
Webb, Norman Keith, B.A. (*Cantab.*), Stud.I.C.E.
Webster, Keith Coverdale, Stud. I.C.E.
Webster, Leon Stanley, Stud.I.C.E.
Williams, Michael Stafford, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Wilson, Stanley, B.Eng. (*Liverpool*), Stud.I.C.E.
Woodwark, Edwin, B.Sc. (*Leeds*).
Wraight, Allen John, B.Sc. (*Wales*).

and had admitted as

Students

Allan, Donald East.
Anderson, Alastair William.
Armstrong, Frank.
Ascough, Donald John.
Atkinson, Joseph Kenneth.
Barclay, John.
Bell, Alexander Nicholson.
Bickley, John Aubrey.
Carpenter, David Gillard.
Close, Kevin David Patrick.
Coates, William Muir Nelson.
Corney, Gerald Walter.
Cramp, Gerald.
Croft, Gordon Rodley.
Cunningham, Peter Ramage.
Davies, Peter.
Dumbleton, Brian Muir.
Duncan, John David.
Ferguson, Donald.
Fozard, Harold.
Gardner, Gavin.
Garrity, Kenneth.
Goodman, Neil Anthony Harford.
Graham, Dugald Carmichael Paterson.
Graves, Peter.
Gray, Robert Stevenson.
Harris, John Roger.
Hartley, Ian Finlay.
Harwood, Thomas.
Heasman, Brian George.
Herrick, David William.
Holt, Frank George Philip.
Hooper, Patrick Norman.
Howlett, Ronald William.
Hughes, Barry Peter.
Jackson, John Keith.
Kemp, John William.
Keyte, Philip John.
Laing, Gordon William.
Laird, Stuart Walker.
Lay, Maung Tin Maung.
Lovering, Frederick Graham.
MacAlister, Donald Duncan.
McFadzean, Matthew.
McIlroy, Peter Kirkpatrick.
Mackey, Eric Thomas.
Maguire, Francis Gerald.
Maheson, Arumugam.
Milner, George Richard.
Morris, Bernard.
Munns, Thomas Trevor.
Nicholas, Howard Brian.
Norris, George James.
Parr, John Anthony.
Phillips, Michael James.
Ponnudurai, Jeyaratnam.
Pougher, Clive Sidney.
Race, Douglas Cyril.
Ratcliffe, Robert Michael.
Reay, Geoffrey Cecil.
Roe, Michael William.
Rowland, Peter John Howard.
Russell, Dennis.
Sallis, Paul Kevin.
Scriven, John Cooke.
Seath, Alexander.
Seddon, Philip Anthony.
Sketch, William Anthony James.
Smith, George.
Stephens, Clayton Rayner Wilfred.
Stuart, John Forbes.
Taberner, John Pinder.
Taylor, David.

Taylor, Howard Royce.
Teal, John Geoffrey.
Thomas, Philip Allen.
Thompson, Paul Binstead.
Turnbull, Jeffrey Alan.
Vickers, Rex Adrian.
Ward, Wilfred Martin.
Ward, William.
Wilkes, Bernard Stanley.
Wilkin, Raymond Edmund.
Wilkinson, Kenneth Ralph.
Williams, Peter Gwilym.
Williams, William George Anthony, B.Sc. (*Wales*).
Wilson, Anthony John.
Winters, Trevor.
Wright, David Eric.
Yardley, Dennis Vernon.
Young, Ian Victor.

The following Paper was presented for discussion and, on the motion of the President, the thanks of the Institution were accorded to the Author.

Paper No. 5922

"Modern Developments in Surveying Methods and Instruments"

by

Alfred Stephenson, O.B.E., M.A., F.R.I.C.S.

SYNOPSIS

Developments which have occurred in all branches of surveying are treated in the Paper, branch by branch, with no attempt to confine the discussion to those developments which appear to be of direct use to the civil engineer.

The main developments in field astronomy are that the surveyor has accepted the navigator's "position line" method, and that accuracy and speed of observations have been increased by the use of automatic timing apparatus and modern theodolites. Reference is made to Roelofs' "solar prism" and to the "Star Almanac for Land Surveyors."

With regard to linear measurements for control surveys, the Paper discusses the Bergstrand method of "modulated light waves," and the Gee H, Shoran, and Decca methods, all of which are suitable for measurement of long distances. For short distances, the greater precision of reading provided by the glass-circle theodolites and special tacheometers has facilitated the increased use of optical methods.

The effect of the glass circle on modern developments in angular measurement is stressed. A recent British method of circle division is described and also a recent small Continental theodolite.

The only important advance in levelling is demonstrated in the new Zeiss Ni 2 level, in which the levelling tube and tilting screw are replaced by an automatic "compensator."

With reference to air survey, the Paper deals with two developments: (i) computation of minor control points by aerial triangulation, using a simple comparator and prints made from films; and (ii) the compilation of railway and factory site plans to a scale of 1/500.

The controlling factors in contouring from air photographs are also discussed.

Introduction

A Paper with a title beginning "Modern Developments . . ." must inevitably be disjointed and have the appearance of a list of different methods and new or modified instruments, but in spite of this it will be seen that there are one or two common factors which have dictated the changes in the past 10 or 20 years. Throughout all branches of surveying the aim has been to get more accurate results with greater speed and with less effort than before. The demand for maps is greater than ever, and in spite of increased financial grants to government departments—the main producers of maps—an enforced economy is still the main dictator

of policy so far as methods are concerned. Development in instrument design has fortunately not been controlled in quite the same fashion, especially on the Continent whence most of the innovations have come in the past decade. On the Continent the instrument maker has virtually told the surveyor what instrument he should use, whereas in Great Britain the instrument manufacturer has produced a combination of what he has been asked for and what he thinks suitable, and since no group of surveyors ever seems to be able to state exactly what it wants at any particular time, the combination has not been very productive. The design of the modern instrument, and more particularly its cost, are very much controlled by modern production methods, in that today the technique of the craftsman is confined to the experimental workshops; once the factory stage is reached the inevitability of mass production is the controlling factor.

In order to give some form to this " list," it is proposed to consider the developments, as they occur, in the three main branches into which the surveyor's work can be divided, and not to describe only those developments which directly affect the civil engineer at the moment. A more detailed description will be given of such developments, but it is felt that since most branches of the surveyor's work are closely related to that of the civil engineer in certain projects, it is as well at least to refer to the developments in all branches.

The main task of the geodetic and topographical surveyor is to measure and delineate the physical features of the earth, whilst the detail surveyor is concerned with mapping the artificial changes that have been made to the natural surface. Today these separate divisions are combined in the title of " land surveyor," and perhaps it is worth recording that in 1947, for the first time, the members of the land surveying profession formed themselves into a professional body under the auspices of the Royal Institution of Chartered Surveyors. The work of the land surveyor is divided into three main stages: the absolute fixing and orientation of a particular distance and direction on the earth's surface; the provision of a control framework including and extending from the absolute fix; and the filling-in of the detail survey within that framework. It is in the last stage that the civil engineer has most in common with the surveyor, but there are occasions when the engineer must use precise triangulation methods and at times the need arises for a precise determination of azimuth and position.

Field Astronomy

In field astronomy there has been no basic change in method so far as the most precise determinations are concerned, although mechanical aids for quicker and more accurate recording have been introduced (see below). For those observations where an accuracy of 1 or 2 seconds of arc is

sufficient, there has been a bias toward the navigator's method of position line fixes, a method far from new, but—like other changes to be mentioned—one which has become more acceptable with the improvement in theodolites. One reason for its more common use is the speed with which a complete fix can be made without having to make an elaborate star programme and being tied to the observation of a particular star at a particular time. Elaborations exist, but basically all that is required are the altitudes (which should be as nearly equal as possible) of four stars, one in approximately the middle of each of the four quadrants of the sky, and the times of the observations. From each altitude, a position line (on which the observer's position must lie) at 90 degrees to the azimuth of each star is computed, and from the figure formed by the four position lines the most likely position of the observer is determined. A full programme would entail observing twelve or sixteen stars (the same four stars can be used more than once) and the final position would be the centre of the circle of best fit to the figures formed by the twelve or sixteen position lines. A great advantage of this method is that a constant error in altitude, such as might result from observing on one face of the theodolite only, merely alters the shape of the figure symmetrically whilst making no difference to the position of the centre of gravity of the figure. To be able to rely on observations made on one face means a very great saving of time, even with the modern theodolite. Nor need time be wasted in the identification of suitable stars since, as a result of the observations made (time and altitude), the star can be identified later by use of the formula $\frac{d\zeta}{dt} = \sin \alpha \cos h$, where $\frac{d\zeta}{dt}$ denotes the rate of change of zenith distance and α is the azimuth and h the latitude. Then, by using the altitude, azimuth, and approximate latitude, the declination and hour angle (and subsequently the right ascension) are found, which makes identification in the star almanac possible. Further simplifications of this method for more rapid fixes have been made in recent years by Dr de Graaff Hunter.[1]

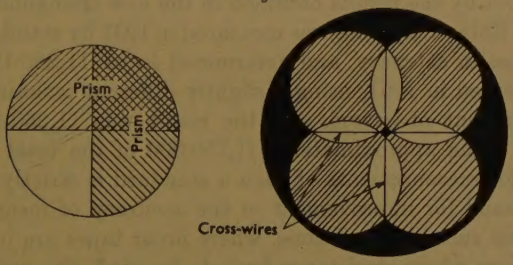
The accuracy of timing observations has been considerably increased by almost eliminating the human factor. Dr de Graaff Hunter[2] has designed an eyepiece which can be attached to a comparatively small theodolite, consisting of a movable shutter which operates directly in front of a scale engraved in glass lying in the focal plane of the objective. The scale can be rotated and used for observing a star's passage in either azimuth or altitude. The shutter opens automatically every 3 seconds for a period of 70 to 100 milliseconds—a sufficient time to record the star's position on the scale, and during which time there will be no appreciable movement. The opening of the shutter is controlled by the chronometer, thus giving the accurate chronometer time for each recording ;

[1] The references are given on p. 405.

for longitude observations this has been further improved in that the time signal can be linked up in such a way that the " pip " corresponding to the second during which the shutter opens is omitted, and no chronograph is therefore necessary.

A recent device which has increased the accuracy of sun observations is the " solar prism attachment " of Professor R. Roelofs of the University of Delft.[3] The attachment, which is mounted on a hinge in front of the object glass of the theodolite, consists of two small prisms mounted perpendicularly to each other, one in front of the upper half, the other in front of the right-hand half of the lens. The effect of this when pointing at the sun is clearly seen in *Figs 1*, where the overlapping images of the sun form a bright cross which is the target for the cross-hairs. The bisection of this target by both vertical and horizontal hairs provides a pointing of an accuracy which is claimed to be equal to that obtained

Figs 1



PRISM ARRANGEMENT : FOUR IMAGES OF SUN
(ROELOFS' SOLAR PRISM)

when intersecting a star. There is no difficulty of tangential settings, nor is there any confusion in choice of quadrants, and the cross-hairs are always clearly visible against the sun's images.

One further change in the sphere of field astronomy which should be recorded is the introduction, in 1951, of the " Star Almanac for Land Surveyors." [4] The users of nautical and air almanacs had become so specialized in their methods at the close of the 1939–1945 war that in no one almanac of that period could the land surveyor find exactly what he wanted ; even if all the information he required had been there, it would have been included amongst much unnecessary matter in a cumbrous volume. The new almanac contains only such material as the land surveyor needs, and is reduced consequently to 66 pages. The geodetic surveyor must, of course, continue to use the comprehensive volume of " Apparent Places of Fundamental Stars." With a much smaller number of stars to deal with, it has been possible to give values at more frequent intervals and to adopt the navigator's methods of using the Greenwich Hour Angle (G.H.A.) of the Sun and Aries, together with the values E and R (instead of the old method of equation of time and sidereal time at

00 hours, Greenwich Mean Time), a form which dispenses with the tedious methods of conversion from mean to sidereal time, etc. The adoption of the " critical table " for tabulating certain values is a very great improvement, and obviates the need for any interpolation.

Control Surveys

Linear Measurement—Long Distances

The second section of the surveyor's work dealing with the establishment of control can be considered in two parts, namely, the linear and the angular measurements. In linear measurements of the highest accuracy over lengths of about 5 miles there has been no change in method and, so far as the accuracy required is concerned, there appears to be no need of change. Accuracies obtained are still far in excess of the accuracy with which the measurement can be incorporated into a triangulation scheme. This is borne out by the results obtained in the new triangulation of Great Britain. The Ridge Way Base was measured in 1937 by standard methods, with invar tapes in catenary, and determined to be 11,260·1931 metres.[5] It was re-measured in 1951, using a slightly different technique, different tapes, and different observers, and the result was 11,260·1865 metres, the difference being approximately 1/1,750,000 of the total length.[6]

The need for measurements of such a standard is strictly limited, but there is a demand for improvement in the accuracy of measuring longer distances in less suitable conditions, where invar tapes are impracticable. Under conditions where steel tapes have to be used, the variation in the temperature of the tape is still a source of error. The determination of the average temperature of the tape itself is almost impossible by the ordinary thermometer and it has been recorded, for example, that in air conditions of 85° Fahrenheit a steel tape has shown an expansion appropriate to a temperature 20° higher than the air temperature. A possible solution to this difficulty is to standardize the tapes in terms of their electrical resistance and to observe the resistance during the field measurement. The method is being practised in Australia, but its accuracy does depend on being able to maintain the constancy of the resistance of the standard resistance coils, in varying field conditions.

It is in connexion with linear measurements that the development in electronics most directly affects the surveyor, and there are signs that, in the not-too-distant future, electronic methods of distance measurement and of computing may be widely used. Electronic methods were very highly developed during the 1939–1945 war for air navigational purposes,[7] and it is not surprising that adaptations of some of these methods, such as " Gee H," " Shoran," and " Decca," have been of most use to the surveyor so far. But for the present discussion it would be better to take a later development first and consider an instrument designed in Sweden, by Mr E. Bergstrand, for the accurate measurement of distances by the use of

modulated light waves and a special electronic receiver.[8] Both this and the Shoran method depend upon an accurate knowledge of the velocity of light and its change with varying atmospheric conditions, and it is interesting to note that Bergstrand used his geodimeter to determine the velocity and obtained a value (*in vacuo*) of 299,793·1 kilometres per second (186,283·4 miles per second) with a mean square error of $\pm$ 0·2 kilometre per second. Another recent determination of this constant has been made by Aslakson,[9] using the Shoran method, which gave a speed of 299,794·2 $\pm$ 1·9 kilometres per second. Two other recent determinations have been made by Dr L. Essen [10] (299,792·5 $\pm$ 3 kilometres per second) and Dr K. D. Froome [11] (299,792·6 $\pm$ 0·7 kilometres per second).

Very briefly, the principle of Bergstrand's geodimeter is that rays of light are transmitted from a concave mirror in a beam towards a mirror at the other end of the line to be measured ; they are reflected from the second mirror and picked up on an amplifying photo-electric cell at the transmitting end. By means of a crystal-controlled oscillator, a series of high-frequency oscillations are transmitted, which have the effect of varying the intensity of light at the source of emission and at the same time varying the sensitivity of the photo-electric cell with the same frequency. When the reflected waves are received on the cathode of the photo-electric cell they vary the intensity of the current according to the variations in intensity of the light. The phase difference between the tension directly received from the crystal-controlled oscillator and that due to the variations in the intensity of the reflected light will be proportional to the distance away of the reflecting prism and may be used to measure that distance.

The geodimeter has now been tested over a number of lines forming sides of first-order triangulation, and in every case the difference in length was of much the same order as the mean square error of the " trig " length itself, and in no case was the difference, expressed as a fraction of the length of the line, more than 1/200,000. The lines ranged in length from 11,000 to 36.000 metres.

This means that lengths can be measured directly to an order of accuracy equivalent to that obtained in computing the side lengths of a first-order triangulation, and suggests a possible replacement of triangulation by " trilateration," or the more frequent use of a check-base, which would decrease the necessity of such a high order of accuracy in the initial base line. It might well be used also in the measurement of distance in precise traversing for the purpose of spanning large gaps. This trend towards the possible greater use of direct linear measurements is also noticed in the use of Shoran radar and in optical measurements of distance, two methods to be mentioned later. There has already been a considerable decrease in the bulk of the geodimeter apparatus—the latest model weighs 130 lb. and has a power consumption of 175 watts.

The geodimeter is likely to have a more direct effect on the ground

surveyor in the next few years than the purely electronic measurements by radar. As yet, the surveyor has only made use of air-to-ground radar, and no specific ground-to-ground radar apparatus has been designed with the higher frequencies that are in use at present. The principal uses of radar as an aid to surveying [12] are for navigation in air-survey flying, provision of control to assist plotting from air photographs, and for the measurement of long distances in what is known as "trilateration." In all cases it is extremely expensive and can in general only be used economically by surveyors in government departments who can use apparatus supplied to other government departments for navigational purposes. This generalization refers to Gee H and Shoran, which are systems using the pulse technique, and does not apply to the Decca system, which radiates continuous-wave signals.[13] Once the Decca stations are installed, the system is available for all who are equipped to use it, such as the Royal Air Force photographic aircraft, from which all photographs used by the Ordnance Survey are taken.

The use of Gee H has considerably increased the economy of survey flying by making it possible to fly parallel courses with constant overlap, without any possibility of gaps through poor flying. If cloud should appear in certain areas then it is possible to return later and fly again exactly over the previous track to take photographs in place of those rejected. Flying at a constant distance from a single ground station means keeping to a circular track, but that is a minor disadvantage that must be accepted. With Decca, the flight lines are different in form, but the result is equally successful.

The use of radar as a direct control to aid the plotting of the air photographs for accurate mapping (as opposed to war-time mapping) is limited. If the absolute position of the aircraft could be fixed to a sufficient degree of accuracy at the instant of exposure, and the camera tilt determined, then the need for ground control would be negligible. The accuracy obtainable at the moment is insufficient, however, since the measurement is subject to errors in :

(1) radar range, which might be of the order of 25 metres ;
(2) velocity of propagation by which the radar range is converted to distance ;
(3) height of aircraft above the beacon ; and
(4) knowledge of the position of the plumb point.

The position of the plumb point can be determined to within 5 metres from an altitude of 15,000 feet by analysis of the photographs, so that, providing a tilt analysis is made, the random error of any fix will be about 30 metres with the present apparatus. This operation requires at least two beacons on the ground, on sites that have been accurately fixed and from which there is an optical range to the aircraft. It is doubtful, therefore, if radar control of this type is economical, but a

compromise between this and the normal procedure for navigation has been found useful.

For topographical mapping from air photographs, on a scale of 1/50,000, where flying has been at 15,000 feet, the Directorate of Colonial Surveys has compiled maps by the slotted-template method. This is a well-known method and involves the principle of joining together three overlapping consecutive photos of a strip, by intersecting points common to the three, by means of slots radial from the three principal points of the photographs. When this is done for a strip of photographs tied down between two ground control points, the intersections are automatically adjusted by the movement along the slots of the studs holding them together. This adjustment also places the principal points of the photographs at their correct relative distance apart, and the lines joining them in their correct relative orientation. If these principal points can be placed in their relatively correct position straight away, a great deal of time is saved, and it is for this additional purpose that the navigational radar beacon is used. If the camera is vertical at each instant of photography, and the aircraft exactly on its radar range, then the principal points will all lie on a curved path on the ground corresponding to the aircraft range. The track can then be plotted on the slotted template grid and the strips of photos assembled along the track. Assembly in this way decreases the amount of ground control required.

A further use of radar is for the measurement of long lines (200–300 miles) and has a special application in linking up island systems to a mainland survey, or in producing a large-sided triangulation over vast areas, such as in Canada, where development is taking place in areas where it will be many years before the ground triangulation will be completed.

The method used is known as "Shoran" [14] and entails the crossing of the line to be measured, by an aircraft which records the ranges from the two beacons, one at either end of the ground line. These are recorded by an automatic observer during flight and the curves of the ranges are plotted on a graph, the range at the time of crossing the line being deduced from the minimum of the curve. The accuracy of such measurements depends upon: (1) the frequency of the observations near the crossing; (2) the estimation of the time of the electrical delays; (3) the velocity of propagation; (4) the heights of the beacons and aircraft; and (5) the range readings themselves.

It was when investigating the velocity of propagation by working back over a known distance that Aslakson arrived at the figure of 299,794·2 kilometres per second referred to previously. The value for the refractive index is obtained from observations taken from a weather plane at the time of measurement. The determination of the height of the aircraft is made from barometric heights, for lack of a more satisfactory method, and even when using an observed temperature gradient this method may involve errors of 1 per cent of the flying height. The main source of error,

however, lies in the range reading ; with Gee H this can be read to 0·0015 Gee units, which is equivalent to a probable error of ± 15 metres.

Since the 1939-1945 war, Shoran has been used to a considerable extent, and the Australians and Canadians have demonstrated that long lines can be measured to produce a triangulation equivalent to the second-order triangulation, although some azimuth control is necessary on the very long lines. The United States Coast and Geodetic Survey, using Aslakson's new figure for velocity, has obtained results approaching geodetic accuracy. These experiments were carried out in Florida, where fifteen long lines, ranging from 30 to 320 miles in length, were measured ; the largest disagreement with the geodetic triangulation was 15 feet in one line.

Shoran methods therefore have their particular value in the special conditions where very long lines are required, as in long distances over water or desert. For shorter distances the geodimeter is very much more accurate, the minimum distance which can be recorded being of the order of 15 centimetres, compared with 15 metres when using Gee H.

One of the difficulties in developing any apparatus for ground-to-ground radar measurements is the even greater uncertainty of the velocity of propagation where the path is likely to be affected by near obstructions. A mere uninterrupted line of sight may not be sufficient, since the effect of reflexions from near obstructions would have to be considered, especially with the use of longer wave-lengths. Long-wave methods, such as the Decca system, can be used from island to island or along coast lines, and Decca is in fact extensively used, where it is available, for tracking survey ships engaged on hydrographic work. Further experiments with this system for land survey purposes are in progress at present, making use of mobile stations.

Linear Measurement—Short Distances

In the measurement of smaller distances no new methods have been devised, but some old and hitherto little-used methods (at least, so far as Great Britain is concerned) have become more acceptable. The methods referred to are the optical measurements of distance, using a subtense base or a self-reducing tacheometer. There appear to be three reasons for the adoption of these methods in recent years : first, the improvement in instruments ; secondly, the suitability of rapid traverse methods for fixing ground control for air surveys, where only the control points and no other detail are required ; and thirdly, the greater difficulties experienced today in measuring distances on the ground, owing to more intensive cultivation, many more owners of property to be dealt with, and the increased number of buildings.

The two great advantages of subtense methods are that the measurements are made regardless of the nature of the ground over which the distance is required and, secondly, the distance computed is the horizontal

distance, even though theodolite and subtense base are at very different levels. Assuming that, with modern instruments, the subtended angle can be measured to an accuracy of 1 second and that the accuracy of the base is known, whether it be a 2-metre invar bar or a 500-foot base, then the ratio of subtense base to computed distance (from 1 in 10 to 1 in 35) can be selected according to the ultimate accuracy required, a choice which will also determine the speed of operations. The error of the measurement is proportional to the square of the distance directly measured, so that in measuring a distance of 2,000 feet by means of a 2-metre invar subtense bar, one direct measurement could be made (assuming an accuracy of 1 second in the subtended angle) with a relative accuracy of 1 in 690, or by ten subdivisions of 200 feet with an accuracy of 1 in 20,000.

The length and form of the subtense base will vary with conditions. For example, subtense bars are made which support two targets accurately centred at the ends of a 2-metre invar wire under tension. At the other extreme there is the Hunter Short Base Equipment, which consists of three targets set out in a straight line and between which are suspended two 80-metre invar tapes in catenary.[15] The slope and sag of these tapes are measured by theodolite from the target at one end of the tape, in order to determine the corrected length of the base. All three targets are observed (and these can be raised to 12 feet above the ground), the subtended angle from the ends of one tape serving as a check on the other. Using a 10 to 1 ratio, distances of a mile can be measured directly to an accuracy of 1/100,000, and this distance can itself be used as a subtense base for further extension. Such a method might well be used for the measurement of a base line for an independent control survey, say, for a large hydro-electric power scheme. Between the extremes of a 2-metre bar and the 160-metre base, any suitable length can be selected and measured by any suitable means available, which is yet another advantage of the subtense method.

The precise subtense bar was first introduced many years ago in connexion with the photo-theodolite with its new glass measuring circles, and provided a means of determining the base length for the stereoscopic pairs of photos. For this purpose, tripods with special levelling heads were supplied, which made it possible to interchange theodolite, camera, and subtense bar without altering the position of the mounting. A similar scheme is now adopted by most theodolite manufacturers for what is known as the "Three Tripod Traversing Equipment," which includes theodolite, targets, measuring heads, optical plumbs, and beacons—all of which are interchangeable on the special tripods. This equipment is admirably suited to the further use of subtense methods.

The second optical method of measuring distances is tacheometry, a practice which, although extensively used overseas, has not been developed to any great extent in Great Britain.[16] No British firm today makes a self-reducing tacheometer. The Ordnance Survey, in making the new 1/1,250

survey of Great Britain, has found that it is not so convenient to make as many measurements on the ground today as it was in the first survey, when all detail was put in by chain and offset. Control for this detail has usually been provided by tape and theodolite traverse, in the form of control points 1,000 metres apart, to an accuracy of 1/10,000. To replace this satisfactorily by optical methods, it would be necessary to have control points 500 to 600 metres apart, when an accuracy of 1/5,000 would be sufficient. Experiments have been made with three modern self-reducing tacheometers, and it is apparently quite a practicable proposition to achieve accuracies, in traversing over lengths of 500 to 600 metres, of about 1 in 5,000. In the process of making such a control traverse, further points of detail are fixed from each traverse station by tacheometry, which provide sufficient material for the final detail surveyor to work from.

The principle of the direct-reading self-reducing tacheometer, which recently has become common to most manufacturers, is that of the Zeiss-Bosshardt instrument. In this instrument two images are observed, one being the direct view, the other a displaced view passing through two identical achromatic wedges forming a parallactic angle of 1/100. When the telescope is horizontal, the staff reading (a horizontal staff is used) equals the horizontal distance, and when the telescope is tilted through an angle α, the wedges are rotated in opposite directions through the same angle and the image displacement is reduced proportionately to $\cos \alpha$. The zero of the staff has a vernier scale which in the field of view is superimposed on the required reading farther along the staff, and the coincidence setting is made by means of a parallel-plate micrometer, giving readings to the nearest millimetre on the staff. This type of instrument does not measure altitude differences automatically. (See p. 406.)

Self-reducing tacheometers are expensive instruments but attachments are made which can be fitted to the ordinary theodolite. The latest of these is the Wild D.M.I. Precision Telemeter, which is a distance-wedge attachment, fitted over the objective and balanced by a counter-weight at the eye-piece end, a micrometer being used for the final reading. A similar attachment is now made in Great Britain.

Angular Measurements

Concerning angular measurements, frequent reference has already been made to the accuracy of the modern theodolite. The achievement of these high orders of accuracy is not new, but the ease and speed with which it can be done are new, and are the result of experience and gradual development of the glass circle, which is now more than 25 years old. The clear divisions of the glass circle and increased illumination made possible by the glass led to much greater magnification of the divisions, and this in turn required greater accuracy of circle dividing and a comparably accurate means of micrometer setting. The result is that, today, a theodolite with

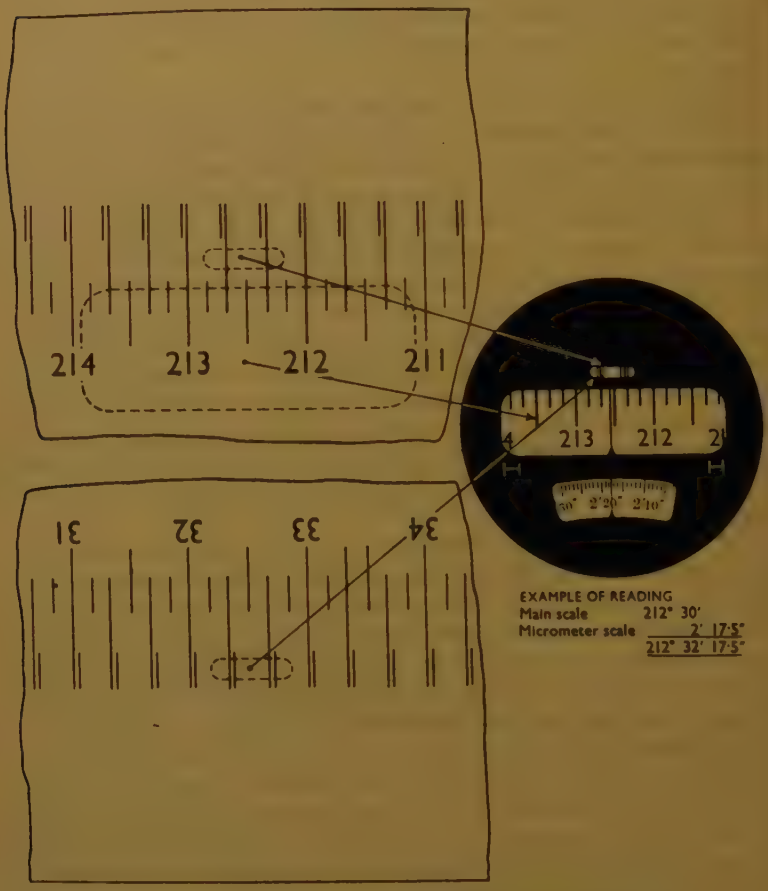
a 3-inch circle is capable of being read direct to 1 or 2 seconds of arc by automatically giving the mean of two readings 180 degrees apart on the circle. To accomplish this has not been a simple task, and new and improved circles are still being produced. The complications arise chiefly with what is now called the " No. 2 Type," or " one second " instrument. The " No. 1 Type," corresponding to the " engineer's 30″ vernier theodolite " reads to 20 seconds direct and by estimation to 5 seconds. It has glass circles but relies on a reading from one side of the circle only, which makes the graduation problem a direct and fairly simple one.

In the " one second " type of instrument, where the graduations striding the index mark at one end of a diameter are projected to the other end, the two images of the nearest graduation to the index (one 180 degrees different from the other) appear separated, and the movement necessary to bring them into coincidence can be calibrated to record the interval required. Instrument-makers have done this in various ways and the coincidence setting of the direct and inverted images of the Zeiss and Wild instruments, and the " light-gap " method of the Tavistock theodolite, are well known. There is considerable difference of opinion, however, on which is the better method—the coincidence or symmetrical striding—and in view of what has been said about the accuracy and advantages of the " one second " instruments it is of interest to describe briefly the latest method used in Great Britain by Messrs Hilger and Watts in their Microptic No. 2 theodolite. *Fig. 2*, which shows this method, is almost self-explanatory.

In order to avoid the confusion of overlapping numbers when half of the circle is superimposed on the other half, alternate circle graduations have been lengthened and the projection from one end of the diameter is taken from the inner unfigured part. The figured part of the circle is graduated in 10-minute intervals, but only the 20-minute divisions are extended and at the inner end of these a short parallel line has been engraved which provides the second division of the " striding pair." All these divisions are engraved at the same time with one revolution of the dividing machine, and the accuracy achieved is comparable with that of the systems already referred to. A test was recently made by C.I.E.M.E. to determine the accuracy of the graduations, and an angle of 60 degrees was measured on both faces on 72 zeros at intervals of 5 degrees. The mean Face Left and Face Right readings were found and the departures from the total mean were less than $\pm 1\frac{1}{2}$ second, and 90 per cent were less than ± 1 second. To benefit by this accuracy the micrometer system must be such that a series of settings can be made and read to a similar degree of accuracy. This is accomplished by moving the image of the double line, which is the projected image, until it evenly straddles the nearest single image, all divisions but the two adjacent 20-second divisions and their double counterparts being masked out. The movement is made

by a micrometer screw, rotating a tilting-plate refractor which in turn displaces the " double division " image towards the stationary single one. The latter is the figured image and, because it does not move, the reading of the index on the main scale gives the correct reading within the limits of estimation. This is not possible in most modern theodolites, where no

Fig. 2



Diagrammatic Arrangement of Circle Graduations and Field of View

estimation can be made from the main scale, which is a disadvantage when setting the scale to a particular reading. The micrometer scale, which is connected to the refractor, is graduated to single seconds.

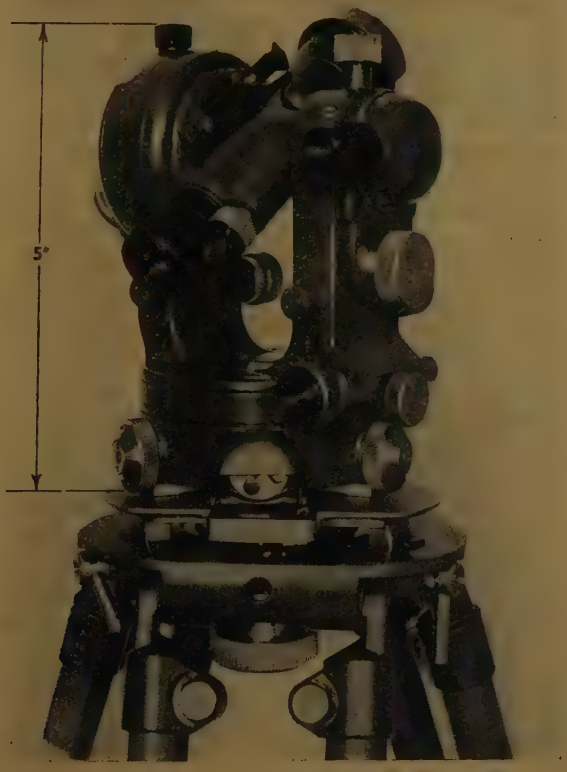
A development which has been possible largely as a result of the use of glass circles is the photographic recording of circle readings. The firms

of Wild and Askania have both fitted their geodetic theodolites (No. 3 Type) with cameras, in such a way that, by the insertion of a movable prism, the light rays coming from the respective graduation lines are photographically registered in the camera. After processing, the readings are made by means of a special screw microscope.

This method of recording is particularly valuable in those observations where speed is essential, such as observations from steel towers, or in " Position Line " observations, where the quicker a set of observations is made, the better are the results. It is also essential in observations such as the triangulation across a large gap (say Denmark to Norway), by synchronized observations on to a parachute flare, where the moving target is kept on the cross-hairs of all the theodolites, and the shutters of the cameras are simultaneously released by radio control.

The automatic recording of readings, whether of theodolite circles or of

Fig. 3



KERN DKM_1 SMALL TRIANGULATION THEODOLITE

rectangular co-ordinates in a co-ordinating machine, shows signs of spreading, and it is likely that many more instruments in the future will have provision for recording cameras.

Other recent improvements on theodolites are shorter telescopes, installation of prism bubbles on the vertical circle, insertion of an optical plumb, and a general streamlining of the instrument. A recent innovation by the Kern company of Switzerland is a theodolite in which the vertical axis is no longer the main bearing, this function being fulfilled by a high-precision ball-bearing movement lying at the outer edge between the tribrach and the upper plate. The main levelling of this instrument is done by means of a tilting plate on the tripod head, and on the instrument itself there are only three fine levelling screws with horizontal axes and helical threads. As a result of these changes, it is claimed that the vertical axes can be fitted more closely; that levelling and setting-up are much quicker; and that the whole instrument is much more compact (*Fig. 3*). This instrument reads direct to 10 seconds and by estimation to 2 seconds, and is comparable in this respect to the 5-inch micrometer theodolite with which many engineers will be familiar. The weight, however, is only 4 lb. and with its case and tripod only 14 lb., compared with 41 lb. for the 5-inch micrometer. It is not suggested that it should be used for all the purposes for which a 5-inch micrometer would be used, but it is a good example of the general trend to achieve results more simply, more accurately, and more rapidly. It represents, perhaps, the limit of compactness which can be attained without the instrument becoming too small for the hands to manipulate.

Levelling

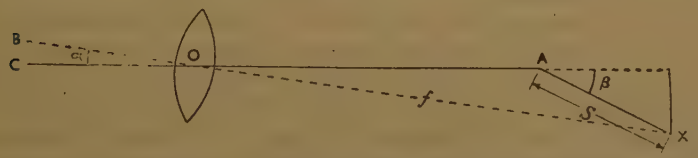
In the field of levelling there has been little change in principle and, apart from the addition of glass circles, optical reading devices, and coincidence bubbles, the only change in instruments has been one of finish rather than design. The one exception to this is the new Zeiss compensating level, in which the spirit level is replaced by a pendulum device. The extent to which the surveyor is dependent upon the spirit level is remarkable, and although the pendulum is under the same control as the bubble it is a welcome sign to see some choice being provided in this respect, particularly if it means that the troublesome effect of an uneven temperature on the spirit level can be avoided. The same choice is now available in prismatic astrolabes, by the recent provision of a model in which the artificial horizon of mercury has been replaced by a "pendulous rigid mirror" (The Willis Pendulum Astrolabe). A less accurate type of instrument, but one using the same principle, is the Cowley Automatic Level, which is used as a builder's level in Australia.

In the Zeiss Ni 2 level the automatic levelling is based upon the fact that, if the line of sight (assumed to be in a state of vertical collimation) is tilted, thereby displacing the centre of the cross-hairs out of the horizontal

line, then by means of a suitably placed and suitably tilted mirror the true horizontal line of sight can be brought on to the cross-hairs, although they are displaced. In *Fig. 4* the horizontal ray CA is reflected at A through an angle β on to the cross-hairs at X, the line BOX being the tilted line of sight.

If the point A is at a fixed distance S from X, then the angle β has to be controlled in such a way that $\frac{\beta}{\alpha} = \frac{f}{s}$. In the Zeiss Ni 2 this is done by introducing a compensator at point A,* between the objective and reticule ;

Fig. 4

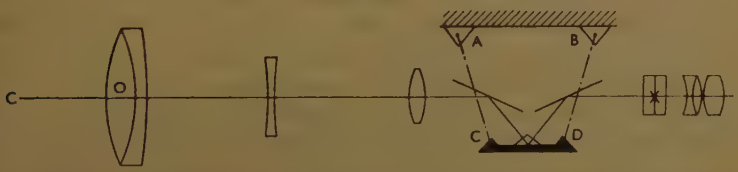


Deflexion of Horizontal Ray CO, at Mirror A, on to Cross-Hairs at X

when the telescope is tilted through an angle α, this compensator so enlarges the angle that the horizontal ray is finally reflected at an angle β on to the cross-hairs (this enlarged angle of tilt being comparable with the increased tilt to the horizontal which a tumbler makes, when the base on which it is standing is inclined to the horizontal).

The compensator is suspended by means of two articulated quadrilaterals (one, ABCD, being shown in *Fig. 5*), in which the joints A and B and their counterparts are permanently fixed to the telescope. The base

Fig. 5



Diagrammatic Arrangement of Compensator in Telescope of the Ni 2 Level

CD is suspended by rods or wires in such a way that it can easily move in each of the spring joints. The only friction therefore affecting the compensator is within the spring material. This very low friction means that a

* Allowance must of course be made for closer sights when the image distance differs from f. Instead of assuming the tilt is about the centre of the objective, as in *Fig. 4*, a point within the telescope is chosen, about which it can be tilted with the compensator remaining accurate for every sighting distance and simultaneously affording a constant tilting enlargement. This point is identical with the anallatic point of the optical system.

damping device is necessary, which is supplied in the form of a normal air damping cylinder. With this arrangement it is claimed that the compensator can set the line of sight truly horizontal in about half a second of time, and that the accuracy is comparable with a level tube of 3 seconds per 2 millimetres sensitivity, which is better than that used for any form of precise levelling. The initial setting is done with a box level and need only be very rough, since the compensator has a balancing range of about 10 minutes.

A test made over 50 kilometres with twenty-three closed circuits showed that the mean error per kilometre of double levelling did not exceed $\pm$ 2 millimetres.

The Ni 2 has two other innovations besides the compensator. The rotation about the vertical axis is provided with an endless tangential slow motion (worm and cog wheel) without any clamping device, the latter being replaced by a permanently adjusted brake which provides the friction between the cog wheel and the tribrach. The other innovation is a new type of focusing control, in which a coarse movement and a fine movement of five times greater sensitivity are combined. By this arrangement, focusing from infinity to the shortest sighting distance requires only one revolution of the knob, except for an additional one-third revolution for the fine setting.

Air Survey

Application of Air Survey Methods to Map Production

Before dealing with one or two modern developments in air survey methods, perhaps it would be pertinent to quote a few figures illustrating the extent to which air survey methods are today being employed in normal map production. The Directorate of Colonial Surveys publishes each year about 300 sheets ($\frac{1}{4}$° square) on a scale of 1/50,000, in which all the detail and contours at 50-foot interval (though not all the sheets are contoured) are plotted entirely from air photographs. In 1 year, the Ordnance Survey has completed, by air survey methods, about 200 sheets of the 1/2,500 survey. These are 1-kilometre-square sheets in which the detail has been plotted from air photographs ; in addition, as an experiment, the control, which in alternative methods is established by tape and theodolite traverse, has in this case been provided by aerial triangulation (see below). In fact, in the past 2$\frac{1}{2}$ years the control for more than 2,000 sheets of this series has been computed in this fashion. At the very much larger scale of 1/500, one air survey company in Great Britain, as a part of its normal production, has made plans of many miles of railway sidings and junctions and numerous plans of the more complicated type of factory site, such as those of chemical works.

None of the organizations referred to can afford to produce maps by uneconomical means, and this volume of work, produced economically

(excluding the experimental work) and by air survey methods, speaks for itself. In particular, it is important to note that two of the examples refer to large-scale mapping in Great Britain and not in those " back of beyond " places to which the less well informed so frequently relegate the air surveyor. There is no doubt that surveying from air photographs is now an accepted branch of surveying, and the air camera, stereocomparator, rectifier, and automatic plotting machine must be regarded as tools of the surveyor's profession just as much as the theodolite and level, and like them should be used to such an extent and at such times as the surveyor thinks fit. Equally, there can be no doubt that any course in surveying that omitted all reference to the air survey methods and instruments would be seriously inadequate.

Methods of Aerial Triangulation

A second factor which must be stressed, and which is brought out by the figures quoted, is that the use of air photographs is not confined to the plotting of detail and that they are being used to provide minor control points to an accuracy equivalent to that obtained by theodolite and tape traverses. This procedure is known as " Aerial Triangulation."

The basic principles of mapping from air photographs are now well established and it must be assumed that they are familiar to the reader of this Paper. Some of the main principles were described in a Paper by B. F. J. Bradbeer and Professor C. A. Hart, published in 1948.[17] It is proposed in the present Paper only to refer to one or two modern practices which have become possible through the development of a particular method, or through the use of certain materials of a particularly high quality.

In mapping at topographical scales it has been customary for some time now to break down the tertiary triangulation ground control into a framework of minor control points, using the photographs themselves in a method known as " radial triangulation." This is done by intersecting points common to three overlapping photographs with rays radial from the three principal points, a method based on the " radial assumption " and confined therefore by certain limitations (chiefly in the amount of tilt and variation in ground height). The method of plotting control points from air photographs now to be discussed was developed as a solution to a problem that arose in the re-survey of Great Britain on the 1/2,500 scale. It was decided to plot the detail of this survey from air photographs, and for this a network of minor control points spaced 400 to 600 metres apart was required. These points had to be fixed with reference to the tertiary triangulation points, which for this purpose had been fixed at intervals of about 5 kilometres to an accuracy of 0·1 metre. The new control points had to be fixed to such an accuracy that the standard error in distance between them was 0·5 metre or less.

To provide such a control by ground methods today, as already

mentioned, is very difficult, and a method was sought by which the photographs themselves could be used, but in which there was to be no dependence upon graphical solutions or radial assumptions, and in which measurements on the photographs could be made to an accuracy of 0·01 millimetre. Such a method, known as " Aerial Triangulation," existed and was being satisfactorily used in the very expensive plotting machines using plate, but not film, photography.[18] The Ordnance Survey problem was to devise a method of aerial triangulation making use of film photography and simple measuring machines.[19]

Basically both methods depend upon the solution of what is known as the " stereogram," which is illustrated in *Fig. 6*. If by some means this " model " can be reproduced by projecting the precise image which entered the camera at the time of photographing, then it should be possible to read off the co-ordinates of any desired point in that model with reference to the axes of that particular stereogram. In a mechanical plotting machine such as the Wild A.5 Stereoautograph (*Fig. 7*), the two plates of a stereo pair are so set that they bear the exact relationship to each other as they did at the time of photographing. The two space rods (S_1 and S_2 in *Fig. 7*) can be mechanically moved so that the pencil point which they control represents the true position in that " model " of the point, the image of which in each photograph is at the other end of each of the space rods (at a_L and a_R in *Fig. 7*). In the viewing binoculars the point is located by a floating mark. The space rods can be made to represent the directions $a_L A$ and $a_R A$ or $b_L B$ and $b_R B$ (*Fig. 6*). In such a plotting machine, however, owing to the size of the plate-holders, the photographs cannot be brought close enough together for the space rods to intersect at the required " model " position, so use is made of what is known as the " Zeiss Parallelogram," whereby one plate-holder and rod is displaced laterally and maintained at a fixed distance (P–Q in *Fig. 7*) from the other. A marker attached to any point on the line P–Q, or its extension, can be used to indicate the " model " position of the photo points on which the space rods are directed.

The relative setting of the two plates to produce such a scale " model " requires correction for the five unknown quantities—the lateral " swing " of each photograph, the fore and aft " cant " of each photograph, and the differential tilt about the air base. Once this mutual setting is achieved, provided the setting of the second photograph is untouched, the first photograph can be removed and the third photograph introduced and set in its correct relation to the second. This provides the second stereogram in which further control points can be identified and their co-ordinates read off on the same system as the first set.

The accuracy of such a method lies in the accuracy of the image which is being referred to and, assuming all initial lens distortions are allowed for, it is still essential for the image to remain stable, and such stability

can only be obtained with plates. There is a method of detecting any movement on films which entails the use of a réseau at the time of photographing, but this can only be used where direct measurements are made

Fig. 6

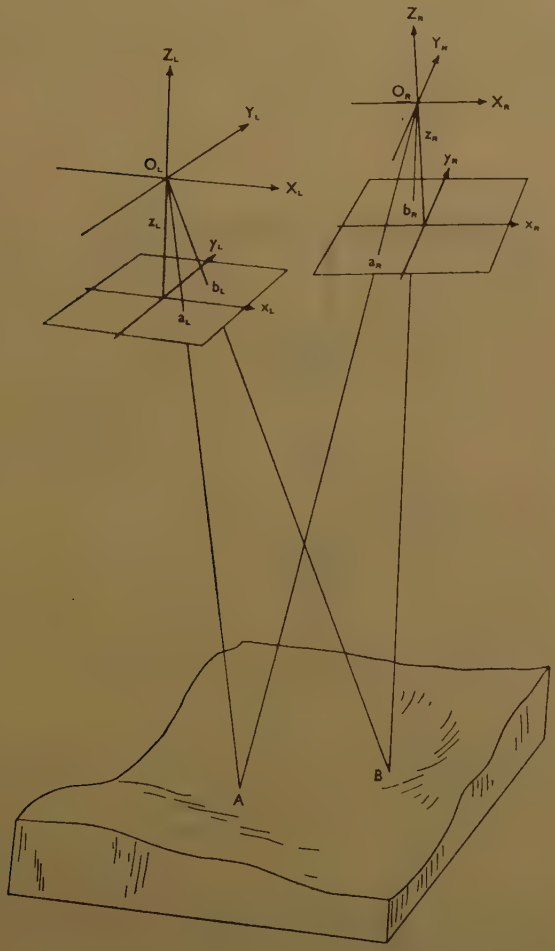


DIAGRAM OF "MODEL" OR "STEREOGRAM"

(This shows the perspective conditions of the two photographs, the two lenses (O_L and O_R), and the object points A and B, in their relative positions at the two instants of exposure.)

on the film or print and cannot be used where the measurement is made by the mechanical movement of a floating mark in a stereoscopic model.

The solution of the Ordnance Survey problem had to be found, therefore,

in the use of films combined with a réseau and a computation that would make use of rectangular co-ordinates measured on the print itself. The method adopted is an analytical one, in which the ideal perspective conditions of the two photographs are again established but this time by analytical reconstruction. In *Fig. 6*, for example, the rectangular co-ordinates of a_L and a_R are read off on the two prints, and the spatial co-ordinates of A are computed on a co-ordinate system common to the two photographs. The method used is an algebraical one involving the use of three-dimensional-direction cosine transformations, and the ultimate

Fig. 7

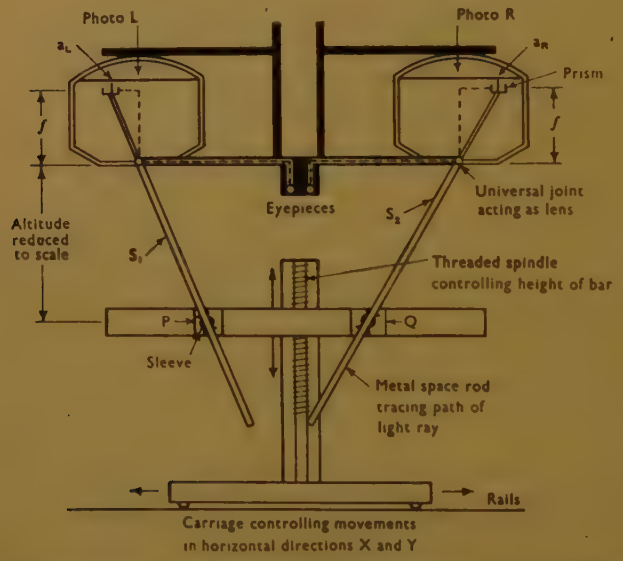


Diagram illustrating the Mechanical Reconstruction of the Perspective Conditions (shown in *Fig. 6*) as achieved by the Wild A.5 Stereoautograph

(Note that the principle of the "Zeiss Parallelogram" has been used, and the space rods do not intersect (see text).)

solution depends on solving an equation with five unknown parameters which are the same five unknowns as those determined automatically in the mechanical method. The independent co-ordinates of each stereogram in a strip of photographs are then combined so that all the control points in one strip are referred to the same system, and that system is reduced to the horizontal. All further computations for adjusting one strip to another and for tying the whole system to a "trig" control are common both to the analytical and the mechanical methods of aerial triangulation.

To return now to the methods by which the rectangular co-ordinates are measured. The instrument used is the Thompson Stereo-Comparator

which, as will be seen later, is a more elaborate machine than is really necessary.[20] It was designed for this particular purpose, before the 1939–1945 war, by Captain E. H. Thompson, R.E. (now Professor of Surveying and Photogrammetry at University College, London). The stereo-comparator has been described elsewhere, and it is sufficient to say here that it provides the means of setting a pair of photographs in such a way that they can be studied stereoscopically through two telescopes, each of which carries a graticule mark. The telescopes can be moved independently over each photograph, a movement which is recorded in rectangular co-ordinates referred to an arbitrary origin. The x axis of the system is parallel to the line joining the centres of the two turntables, and the co-ordinates on the second photograph refer to axes parallel to those of the first but referred to a different origin. The stereoscopic fusion is used to provide a better identification of the point and for recording and eliminating any " want of correspondence " (that is, the difference in the two y co-ordinates of the image points on two photographs of any one ground point, a measurement which enables a tilt correction to be made).

Co-ordinates can be read to 0·01 millimetre, which is justified when a réseau is used in photography. The réseau is engraved on the register glass of the camera and consists of a rectangular mesh of very fine small crosses at 1-centimetre intervals, the centre cross coinciding with the principal point mark placed on the centre of the plate by the makers. Each réseau carries an unique number and an arrow which, when the camera is mounted in the aircraft, points in the direction of flight. The réseau is carefully calibrated on a stereo-comparator and the co-ordinates of each cross obtained relative to the axes of reference. This calibration is made up to four times on four different comparators, giving a standard error on a single observation of 0·01 millimetre, the co-ordinates of each cross being recorded on a calibration chart.

The camera, with its particular réseau in place, is then very carefully calibrated in the field, and lens distortions are measured twice along each of eight diameters at $22\frac{1}{2}$-degree separation. Such distortions are normally least at the centre, and by a slight change of principal distance can be minimized at a distance 12 centimetres from the principal point, which is the part of the photograph in which the minor control point will usually lie. A final list of distortions is then calculated and a diagram of corrections is produced which can be incorporated in the réseau calibration chart.

By using such a réseau it is possible to eliminate distortion in the air film and on positives made from it. In addition, it tends to eliminate errors caused by lack of flatness of the film against the register glass of the camera, and shows up by poor definition of the crosses any lack of contact in printing. A simple stereo-comparator can be used since, the co-ordinates of each cross being known, the maximum distance to be measured will be 0·5 centimetre. The crosses are so fine and small that they do not interfere with interpretation.

The main objection to this method of aerial triangulation has been the very lengthy computations involved in the first two stages of the solution, as referred to above. Fortunately the algebraical system which has been adopted is an iterative one, and lends itself to solution by electronic computers. Very successful experiments have already been made and it appears that the only objection to this economical and simple form of aerial triangulation has now been removed. No extensive comparative ground checks have been made since the réseau has been regularly used, but comparisons made between twenty-nine ordinary " trig " values and values obtained by aerial triangulation without the réseau indicated a mean error of position of 0·61 metre over an area of 180 square kilometres, using 233 photographs with 18 ground control points. The use of the réseau should undoubtedly have reduced this to the order of 0·5 metre, which was the accuracy stipulated in the initial problem.

The important conclusion to be derived from this brief account of both mechanical and analytical aerial triangulation is that air survey can be used, within certain well-defined limits, to provide its own control points to aid the subsequent detail plotting—a procedure very similar to the way in which a plane tabler fixes his own minor control (within the limits of his " trig " control) by resection and intersection, in order to control his plotting of the detail.

Mapping to Large Scales

A brief reference must be made to one further modern achievement by air survey methods, namely, the production of plans to as large a scale as 1/500.[21] Mapping at such scales from photographs has hitherto been impossible because of insufficient definition in the photography, and the difficulty of interpreting the smaller details. To achieve the large contact scale necessary, the aircraft must fly as low as possible, but at the same time a 60-per-cent overlap of photography must be maintained, and there must be no relative ground movement during exposure. Magnification of the contact scale will still be required if the small points of detail expected at a scale of 1/500 are to be accurately identified.

Plans on this scale of complicated railway tracks and of factory sites, such as chemical works, have been successfully produced by mechanical plotting in a Wild A.5 Stereoautograph.

The most important factor in this large-scale plotting is the quality of the image definition as seen in the plotting machine by the operator. Providing that details are clear enough for him to operate the floating mark precisely, there is not likely to be any further loss of accuracy in the enlargement (sometimes 3 : 1) between machine and plotting table. A completely satisfactory definition can now be obtained with the new Wild R.C.7 fully automatic plate camera (*f*.1.170 mm.) and with the corresponding R.C.5 film camera. Films from the latter are sufficiently

stable for the plotting of planimetric detail on paper which is liable to lose shape to a greater degree than the film.

With these cameras a convenient contact scale of about 1/4,000 is obtained by flying at 2,200 feet, and the required standard of definition is obtained with an exposure of $\frac{1}{300}$ second at f 5·6.

A second factor that has helped to make possible this large-scale plotting is the co-operation between the operator, detail surveyor, and map user, in selecting and marking a particular form of ground control before photography. Reference marks (relative to the " toe " of a switch, or " nose " of a crossing in railway surveys, for example) are placed in key positions and certain small but important details can be accentuated in various ways to aid the plotter.

It is not claimed that complete detail can be plotted to a scale of 1/500 entirely from air photographs, but it has been proved that, in certain cases, 80 per cent of the detail can be plotted far more rapidly than by ground methods, and the ground survey of the remaining 20 per cent is greatly facilitated by using reference points plotted from the air photographs.

Contouring by Air Survey Methods

Nothing has yet been said about contouring from air photographs and, so far as the photogrammetrist is concerned, there has been little recent change or development in his methods. The conditions which control the plotting of contours are much less uniform than those required for planimetric control, and the accuracies claimed are therefore more varied. A certain scepticism prevails concerning the accuracies that have been claimed in this respect, but some of these doubts would be dispelled if there was a more general appreciation of the fact that, for three-dimensional plotting, much more control is necessary than for planimetric work, because the stereoscopic setting of a floating mark in the vertical plane is far more critical than in the horizontal plane.

The theoretical accuracy of contouring by air survey methods depends upon the altitude of the aircraft and the precision of the plotting machine, assuming that good photography and adequate ground control are obtained; and it is the amount and quality of the latter that can very seriously affect the theoretical accuracy. It is in this field also that most effort is being made to improve existing methods.[22] There is insufficient space here to do more than list some of the experiments that are being made, but it is felt that this field is one in which the engineer is directly interested, in that it is he who is frequently called upon, or who offers, to provide the ground control.

A most important need is for a greater understanding by the field surveyor of the plotting-machine operator's requirements and his problems so far as control is concerned. This would enable the man in the field to select and fix control points, not only in the most suitable places, but of the form most suitable for stereoscopic plotting with a floating mark.

Above all, however, there must be sufficient control of the required accuracy, and it must never be forgotten that contouring from air photographs is not a miraculous performance that can produce a map without going near the ground. The amount of ground survey may be infinitely less than that required for a contoured survey on the ground in hilly country, but there must still be some very accurate work done on the ground. This is often extremely difficult, but if contours of 10-foot vertical interval, or less, are required, then there is no alternative to providing three control points to each overlap, by some accurate means. If this is done and the points chosen are suitable for stereoscopic plotting, then the theoretical accuracy may well be achieved.

Control for contouring at 25-foot or 50-foot vertical interval in most cases is provided by aneroid traverses between or around known trignometrical points, and the accuracy in this case is controlled to a large extent by the knowledge of the air-pressure regime at the time of observation. Experiments to improve this knowledge of any locality are being made with altimeters that are automatically and continuously photographed. These are distributed over the area so as to provide a wider picture of the conditions than the normal profile conditions which are customary, at present, when working between only two known stations. The altimeters in use are the Wallace and Tiernan pattern, the rack-and-pinion design of which (with its maintained uniform tension) has proved much more reliable and robust than the usual altimeters made in Great Britain, which are based on the Vidi principle of delicate levers.

There are many ways in which this control for contour surveying from air photographs can be improved and extended, including the use of helicopters, but for the present purpose the important point is that it should be realized that much more control is required per overlap for contour surveying than for purely planimetric work, and the extent and accuracy of that control is the chief factor in deciding what percentage of the theoretical accuracy of the plotting machine will be achieved.

Acknowledgements

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The Paper is accompanied by one photograph and six sheets of diagrams, from which the half-tone page plate and the Figures in the text have been prepared.

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Discussion

The Author introducing his Paper, referred particularly to three aspects which he thought were of particular interest to the civil engineer. He exhibited a Wild self-reducing tacheometer together with its horizontal staff, and pointed out that contrary to what was said in the Paper, that particular model of tacheometer did provide the difference in height as well as the horizontal distance between two points. That was achieved by turning the wedges through 90 degrees, thus obtaining a sine-reduction in place of the cosine-reduction. In those cases where the vertical angle was large, a reduction correction was obtained from an auxiliary scale which rotated with the telescope.

A wedge attachment which fitted on to a " one-second " theodolite and which was made by a British firm was also demonstrated, together with an instrument which had been brought to the Author's notice since writing the Paper. That was the Ewing Stadialtimeter which had been made and was in use in Australia. It was not an instrument to be compared in accuracy with the full self-reducing tacheometer, but probably would meet a need so far as engineers' reconnaissance work was concerned.

The basic principle of the Stadialtimeter was similar to the well-known Hammer–Fennel device in which the image of a diagram of curved lines at varying distances apart, indicating the correct stadia interval at different angles of elevation, was brought by optical means into the field of the eyepiece. Mr Ewing's invention was an attachment that could be made to fit either vernier or microptic theodolites and was used with a vertical staff. It consisted of two units, a drum mounted in a box attached to a convenient part of the instrument, such as the upright of the theodolite, in such a position that the second unit, an optical sight, could be attached to the telescope or trunnion axis and made to observe the drum. The sighting mark was the virtual image of an illuminated pinhole which was seen in coincidence with the surface of the drum, which contained a series of curved lines representing the solutions of the usual reduction equations. After sighting the staff the drum was rotated on its axis until the intercept line, which was figured with the valve ($S \times 100$), was observed by the optical sight. The difference of level was then indicated on the external circular scale attached to the drum. The correction to be applied to the slope distance was obtained from a second set of curved lines which ran across the intercept lines.

Field reduction of reduced levels was greatly speeded up by the fact that the circular height scale was mounted on a friction fitting so that it could be turned relative to the drum. Thus the scale could be set to the reduced level of the theodolite station and all height observations made from that station would then be given as reduced levels. The Author had received no field reports of that instrument and felt that its accuracy might be very dependent upon the stability of the material used for the drum.

With the aid of lantern slides the Author then summarized his description of the Ni 2 level and illustrated the rather particular ground-control requirements needed for large-scale surveys from air photographs.

Mr P. E. Sleight said that many civil engineers like himself, who previously had thought that they were qualified to undertake surveying work must have been surprised to see the modern surveying instruments, which were magnificent pieces of work but which would be simply " boxes of tricks " to many engineers. The details which had been given of the modern methods used in surveying emphasized the fact that the young civil engineer should have a thoroughly sound knowledge of fundamental sciences, and particularly of applied physics.

One of the principal changes in the instruments used for astronomical work seemed to be in the speed and timing of observations. That had always been a difficulty in the past. It had not been possible to look at a watch and at the instrument at the same time, and it was not always possible to have a reliable observer.

One innovation which he applauded was the Star Almanac for Land Surveyors. It was much more convenient for observation and for finding out the data required, and much more useful than the Nautical Almanac, which some engineers found very trying to read.

The accuracy obtained in precise measurement over long distances was awe-inspiring. He was particularly interested in the statement that the 1951 measurement of the Ridge Way Base showed a disagreement of 0·0066 metre with the 1937 measurement of the same Base, which was equivalent to about $\frac{1}{4}$ inch in a total length of 7 miles. That was remarkable both for the modern measurement and for the original measurement.

The standardization of tapes in terms of electrical resistance was interesting, but it would appear that the difficulties of maintaining standard accuracy with the small variations in resistance might be as great as those of measuring the temperature of the tape, to which reference was made in the Paper. It was very unfortunate that invar suffered from instability in length, because it was otherwise most attractive in use. It was to be hoped that one day metallurgists would produce a material which was equally attractive but with better characteristics.

It was impossible to avoid referring to the electronic developments used in connexion with the measurement of long distances, since the developments that had taken place in the field were quite spectacular. Specialization in that branch seemed to be essential, and he doubted whether many civil engineers would be able to appreciate those developments without further knowledge of electronics.

The accurate measurement of short distances was, however, something that the civil engineer should be informed upon, and in that field the tacheometric developments were probably the most important. The development of tacheometric instruments, as was shown by the Author, had taken place on the Continent. It was a pity that the Author had not

been able to refer to any British developments, such as had taken place some years ago, when a former Secretary of the Institution, Dr Jeffcott, introduced his self-reducing tacheometer. That instrument was not manufactured at the present time, but those who had used it in the past had found pleasure in the ingenuity of the design. Accuracies of about 1 in 5,000 were quoted in the Paper as being possible with modern instruments, whereas it had been customary in the past to think of 1 in 600 or 700 as being reasonably accurate for tacheometric measurements. The increased accuracy now possible was obtained with increased speed and with much less labour. The improvement in theodolites and levels, both optically and mechanically, had undoubtedly removed some of the spirit of adventure from surveying, and possibly the pupil engineer might regret the loss of some of his excuses for inaccurate readings.

The increasing use of aerial survey methods for map and plan reproduction, both in Great Britain and abroad, was sufficient evidence of the value of the development, and it was pleasing to note that the subject was being given a reasonable amount of space in most modern courses in surveying. Unfortunately, the equipment was not easy to use, it was very difficult to obtain, and one could not simply charter an aeroplane to undertake a little field work for students. The surveyor, however, had very good reason to thank the " Boffins " of the 1939–45 war for the continued development of those devices, which would undoubtedly increase the ease with which he could cover large distances.

In spite of all the modern developments in methods and in instruments, the civil engineer had still to carry out the usual routine tasks in his office ; he had to set out straight lines, curves, right-angles, and plot levels, often with an old four-screw instrument.

Colonel M. O. Collins said that it might be of interest to mention an experiment which the Ordnance Survey had just finished, using tacheometers, and also to mention three items of development which they were pursuing.

So far as the tacheometers were concerned, the Survey had been carrying out an experiment for about a year, and they were now satisfied that they could do planimetric surveys to their standard of accuracy on the 1/1,250 scale with those instruments, provided that the control points on which the work was based were not more than 500 metres apart. The 1/1,250 scale was the largest scale on which the Ordnance Survey now worked. The results of the experiment showed that the cost of the work was slightly less when using the tacheometer, but there was very little difference, and certainly not sufficient to warrant a change-over in equipment and the re-training of personnel in a department as large as the Ordnance Survey. It had, however, been found in certain areas such as railway sidings, docks, and some factory areas, where horizontal measurement was difficult, that the tacheometer had great advantages, and it was being used for detailed survey in that special type of area. The Ordnance Survey had not

adopted the tacheometer, but it was nevertheless a useful addition to the methods at present available for carrying out large-scale surveys.

With regard to the future, one of the interesting things about air survey was, as the Author had stated, how to provide the requisite control. A ground visit was expensive and added very considerably to the cost. The Ordnance Survey had therefore developed the stereocomparator method of providing control, which the Author had described. The department was satisfied that they could control their surveys on the 1/2,500 scale by stereocomparator means, and an experiment was now going on to see whether surveys on the larger scale of 1/1,250 could be controlled in the same manner. The area had been photographed and the control points selected, and the positions of those points would be obtained by normal traverse methods and also by stereocomparator; the results would be compared for accuracy and time in an attempt to analyse which was the best way of doing such a survey.

A further development which was related to the question of stereocomparator control was the application of modern machine-computing to survey problems. There were, broadly speaking, two types of digital computers, the mechanical and the electronic machines. Colonel Collins used the term " mechanical machine " to cover anything which mechanically sorted cards or added data on cards, and could even go so far as to multiply and divide. That type of machine was slow compared to the electronic machines. The work had to be inserted in a series of different stages, and the machines themselves had little or no memory.

The other type of machine was the electronic machine or, as it had been called, " the electronic brain." That worked rather faster. There were only two in Great Britain, namely the A.C.E. (Automatic Computing Engine) at the National Physical Laboratory, and the Ferranti machine at Manchester, which did work for outside interests. They had a considerable memory, and could add two 10-figure numbers together in one ten-millionth of a second. Unlike the mechanical machines, they became inefficient if they had to disgorge results half way through the computation, and that created difficulty.

The Ordnance Survey had now, with the help of the N.P.L., programmed the computation of the stereograms referred to by the Author, for computation by the A.C.E. The iterative solution of stereograms normally took a man with a desk-machine a day and a quarter; the A.C.E. solved it in 3 minutes, so that it was necessary to find a lengthy computation for the machine to do to make it worth while.

The other type of mechanization which the department was investigating was that of their level computations. That was not a problem for the A.C.E., but for the mechanical type of machine. Level computation was comparatively simple, and the main difficulty was the large volume of field data which had to be absorbed; it could be done quite satisfactorily by the punched-card type of machine.

One interesting fact which had been found in using the machines was that it was necessary to alter one's mathematics and the way in which one thought. The machine went the long way round. For many years surveyors, amongst others, had been trying to find short cuts; for example, logarithmic Tables of trigonometrical functions had been produced. The machines, however, could not refer to a Table; they had to produce the same answer from first principles, and that entailed an alteration in the method of solving a particular computation.

The Ordnance Survey were also finding that they might have to alter slightly the procedure in their field work to fit the new computation pattern. Colonel Collins mentioned that he believed that, certainly for organizations such as the Ordnance Survey, the modern machine-type of computing was going to come in a few years. The Ordnance Survey were trying to keep up-to-date so far as they could by contact with the people who were developing the machines, which at the moment were in no way completely developed.

The Ordnance Survey were also trying to develop a new levelling staff, a sectional duralumin staff of tubular construction. Colonel Collins felt that there was one point in instrument design which had arisen in that connexion which was of general interest. A high degree of precision had been achieved in dividing circles for angular measurement and in dividing steel tapes, but very largely there was a tendency to rely on the paint brush as the method of dividing staves, and that hardly gave the same degree of precision.

Mr B. F. J. Bradbeer observed that most civil engineers commenced their training with exercises in surveying, so that they might learn to appreciate an engineering problem, and that later in life they might be able to express their opinions on what should be done to improve an existing position, and do so with benefit to others. It was perhaps fortunate that many civil engineers had done some surveying, and were most likely to have studied geodesy in their college days, and therefore would be able to appreciate some of the finer points put forward by the Author.

The Paper presented to practising civil engineers a reminder and a valuable review of the latest developments, and gave them an opportunity to bring their thoughts up to date again. One aspect of the discussion which should be fruitful was that whereas they all tended nowadays to specialize more and more in their several directions, unless they came together occasionally and discussed those matters they could not learn to help each other; they could not derive the full benefit from those developments without contact and the opportunity to express their views.

The points in the Paper which chiefly attracted Mr Bradbeer were those concerned with modern methods of measurement of short distances. It was of interest from the point of view of the practising engineer to note the increasing awareness of surveyors of the difficulty of measuring on the ground in highly developed country. Moreover, on many occasions deci-

sions were demanded nowadays more rapidly than they had been in the past, and it was not possible to wait for a suitable season. It was often manifestly impossible to force a line through valuable crops, private enclosures, or dense vehicular traffic. He had seen the Ordnance Department at work in Lewes, which was noted for its traffic problems, and for some months he had scarcely seen a tape being used; almost the whole of the work had been done by tacheometric methods, or so he assumed.

In such circumstances as those of the close development to which he had referred, it seemed that optical measurement and/or survey from the air were the only methods available to the engineer and surveyor. An added advantage of those methods was that trial locations of, for example, railways, roads, or canals of some length, could be made without upsetting owners of property, who would otherwise be sensitive to the more obvious implications of a ground survey. The ground survey could cause a great deal of correspondence for no reason at all, and could give rise to a great deal of unnecessary " heart-burning " and waste of valuable time.

Mr Bradbeer had had an interesting experience at a public inquiry recently when challenged as to the authenticity of a proposed new road on the grounds that no surveyors had been seen in the district. Without disclosing too much information, he had been able to confirm that the survey had been adequately made—by air survey and tacheometric means. Several hundreds of miles of roads in Britain had been surveyed with the assistance of air survey and the value of that work would be more apparent were it not that those road schemes were unfortunately held in abeyance. Whilst some remarks had been made about the accuracy of contouring in some cases, he gathered that such discrepancies had been largely caused by the standard of ground control specified and paid for.

The Author had most opportunely emphasized that three-dimensional plotting required more detailed ground control than did planimetric work. By the modern methods described in the Paper it should be possible to specify standards of control suitable for the purpose in view, and if that was done, with liaison and proper understanding between the engineer and the air surveyor, satisfactory results should be obtained. It was comforting to read in the Paper that air survey was now recognized as an accepted branch of surveying. That was of interest to Mr Bradbeer because he had been for many years interested in photogrammetric methods, and there had been times when considerable doubts had been expressed about them.

One of the values of the photogrammetric and air photography type of survey was that the photographs which were produced for the engineer gave not only the survey, but a considerable number of features which might be of the greatest value to him in the matter of land usage, the important question of severance, and with regard to land values when projecting a line such as a road or railway or aqueduct. A trained observer could deduce a great deal with regard to the state of the ground and the soil from such photographs. They were in that respect a permanent

record, and would also be a valuable record of the state of progress of a particular and perhaps complicated project at a particular instant.

Professor E. H. Thompson said that the analytical methods of aerial triangulation which the Author had described was of interest, not only for the large-scale surveying for which they had been used in the Ordnance Survey, but also in small-scale surveying, where it was necessary to provide aerial triangulation in a country which was inaccessible or difficult of access. A great deal of interest was being shown at the present time, and developments would, he hoped, be starting soon which included the development of a new instrument, a new stereocomparator, in which the recording of the observations and, possibly, also the mean of several observations, would be automatic, and thereby provide data in a form suitable for feeding to the automatic computer. That would further quicken the process of completing the triangulation. If that were successful, he was convinced that it would be the most economic and practical way of doing aerial triangulation, because the equipment, in spite of the cost of the electronic computer, was considerably cheaper than the expense involved if the work was done entirely with an automatic plotting machine of the type shown by the Author, since the computer, though expensive, would keep a great many considerably simpler instruments busy.

Colonel Collins had referred to work for the electronic computer. The output of the stereocomparator was very suitable for the electronic computer in the sense that the bulk of the computation, or the worst part of it, was that involved in a single pair of photographs, and the work was precisely the same for every pair of photographs. It was possible, therefore, to feed to the electronic computer the work required for pairs of photographs whether from one strip or from different strips in the same block or even from different blocks. The work was the same, and by a coding system it was possible to feed the results to the electronic computer in any order, and they could be put in the right order when the work came back again. In that way the worst part of the computation could be done, in a sense, piecemeal by collecting as much work as was necessary to keep the machine busy for a certain time and not worrying whether the work actually completed a particular strip or block. That made the computation considerably more flexible.

As Mr Sleight had said, the teaching of aerial survey was now being covered to some extent in courses, but it was difficult to cover it completely owing to the difficulty of learning about the various instruments used, and so on. That had been his experience during the comparatively short time he had been at University College. A diploma course in surveying was conducted there which taught all branches and lasted one year. He had come to the conclusion that it was quite inadequate to deal with photogrammetic methods, and the introduction of a photogrammetric course was being seriously considered, which would again last one year, and in which nothing but photogrammetry would be taught. The students taking such

a course would be expected to have a knowledge of the classical methods before being admitted, particularly if they were surveyors. Courses of that nature had been conducted on the Continent for a long time. One reason why those methods were not being applied in Great Britain so energetically as perhaps they should be, might be that young men were not being fully trained in them. He himself, and, he thought, all those who knew a little about the subject, had learnt it painfully by teaching themselves, and that was to some extent still the case today.

There was one point which he would like to make about the use of tacheometric methods in the Ordnance Survey. It was perhaps a little unfair, as a comparison between ground-taping methods and tacheometric methods, to compare the 1/1,250 surveys of Great Britain, which were to a large extent in towns, in which the taping was over extremely good ground. When the ground was bad and a certain amount of clearing was necessary, taping became difficult, and it might well be that the difference in speed and cost would be greater than Colonel Collins had indicated.

Professor Thompson was convinced that Great Britain had lagged behind the Continent in the production of novel instruments of various types, because the civil engineers in Great Britain appeared extremely reluctant to use any kind of instrument but the most conservative. Reference had been made that evening to the four-screw instrument, and the mere fact that it had been mentioned at all showed the sort of outlook which prevailed. On the Continent, on the other hand, the civil engineer had never hesitated to use the latest instrument.

Adherence to the use of older and more conventional instruments was a very short-sighted policy, because it was in fact far more expensive to use a cheap old-fashioned instrument rather than a costly modern instrument. The Ordnance Survey before the 1939–45 war had considered the question of the various orders of triangulation, and it had proved cheaper to use a theodolite of the modern type on the lower orders of triangulation, although its accuracy was not necessary for that work, rather than to use the old-fashioned instrument. The old-fashioned instrument was considerably cheaper in capital cost but required far more time to use ; and it was in the time taken and not in the capital cost of the equipment that the cost of a survey went.

He asked civil engineers, therefore, to give the modern instruments a trial and to consider that, however much higher the cost might appear than that of the customary instruments, in the long run it would pay to use them and, by giving the instrument maker a market, it would enable him to feel that he could develop unconventional instruments with a reasonable hope of being able to make a living, which up to now in Great Britain had been quite impossible. It had not been impossible on the Continent, however, where the introduction of a new instrument resulted in large sales to civil engineers.

Mr E. W. Cuthbert observed that there was too much of a gulf between the surveyor and the man at the other end of the tape. With modern methods of surveying, as well as with the classical ones, the result was dependent equally upon the man who assisted the surveyor and on the surveyor himself. Not enough attention was given to the training of chain-men. He knew of a survey which was going on in London where the progress was very slow. It had to be done at night, owing to the traffic during the day, and only old age pensioners could be found to act as chain-men; they could not stand up to the severe winter weather when most survey work seemed to be done. When a young man could be obtained, he was often not so reliable as an older one.

So far as civil engineering work was concerned, it was most important that the surveyor should be thoroughly conversant with the objects of his survey. A good deal of misdirected effort was put into finding out details and obtaining information which were not of real use in designing and setting out the work, and it was often found, when the surveyor returned to his office, that he had missed a tie-point which was important in setting out a road or railway, or had not noted services such as drains, etc. The surveyor should know exactly what he had to produce, and he should also know what degree of accuracy was expected of him. There were cases in which great effort had been devoted to producing accurate measurements of buildings which were going to be demolished within the first few weeks of the job, whereas things which were essential had not been measured accurately.

Under the heading "Linear Measurement—Long Distances" the Author had referred to the fact "that in air conditions of 85° F. a steel tape has shown an expansion appropriate to a temperature of 20° higher than the air temperature." That would represent an error of $\frac{3}{20}$ inch in 100 feet, which was probably acceptable for most civil engineering purposes. It would be interesting, however, if the Author would say a little more about the possibility of standardizing the tapes in terms of their electrical resistance where great accuracy was required.

With regard to the Bergstrand geodimeter, it would be interesting to know the effect of the atmospheric conditions on those long measurements and what sort of percentage errors resulted from local differences in temperature and pressure on a very long line. He would also like to know whether it was difficult to align mirrors on the photo-electric cell and whether they remained correctly aligned as the refraction varied over a long line. It seemed to him that there must be a considerable flickering effect, and that a relatively small mirror or photo-electric cell might lose its target.

It was startling to realize the extent to which the surveyor was dependent upon the spirit-level, a fact to which the Author had referred. Mr Cuthbert wondered how the glass tubes of spirit levels of any specified curvature were accurately manufactured. Any information which the Author could give on that subject would be of interest.

With regard to air survey, Mr Cuthbert's experience had been limited to seeing the results of one air survey on a suburban line of London Transport. He agreed that up to a scale of approximately 1/500—or, in railway terms, 40 feet to the inch—the results could be produced with sufficient accuracy for many purposes, but it must be remembered that with many surveys for railway purposes, although the actual plotting was not to a scale much greater than 40 or 20 feet to the inch, the tie-points were surveyed to a great degree of accuracy, and when the points were co-ordinated, they were relied upon in many calculations for curves and the setting out of the works generally. That could not be done by scaling the plan of a survey plotted to 40 feet to the inch; with the combined errors of the photography, the plotting, the inking-in, and scaling, the accuracy was probably of the order of 6 inches on the ground. That must be borne in mind in deciding whether an air survey would pay, when compared with the traditional type of survey with a closed traverse running along each side of the railway, which was plotted after calculating the co-ordinates of the traverse stations.

In many railway works, much of the detail could not be seen in the air photograph. Platform edges were often obscured by overhanging platform roofs, and platform structures could not be surveyed directly from the air; bridge piers and the faces of abutments were often hidden by vegetation, and a certain amount of detailed inspection on the site had to be done by the surveyors to identify signals and to obtain details of drains and so on. There were cases, therefore, where a survey from the air for railway works would not be a good proposition even on an electrified line, where direct measurements across tracks were very difficult.

On the other hand, he knew of one job on a railway where a survey from the air would have been ideal. A survey had been in hand for a proposed depot on what was largely agricultural land, and the only places where extreme accuracy was needed from the point of view of setting out were where the new depot tracks made a junction with the existing main line. The remainder of the topographical features consisted of hedge lines, country lanes, and watercourses across fields. Those could have been surveyed very well from the air, and much time would have been saved. He concluded that it was necessary to bear in mind to what use the survey was to be put before deciding whether it should be an air survey or not.

Mr T. K. Chaplin asked whether the Author could give some idea of the accuracy of radar altimeter surveys from aircraft in relation to elevations obtained from trimetrogon aerial photography, and whether there was any practical method of using radar to measure an aircraft's true elevation as well as its position, and thereby avoid dependence on altimeter observations.

He also asked whether the Zeiss Ni 2 level was sufficiently robust to be carried by a lorry over rough roads. Was any trouble caused by temperature differences within the supports of the compensator? Slight variations

of temperature might conceivably produce disproportionate effects on the angle of the compensator. When working at the extremes of the range of the compensator, did any slight error of focusing cause trouble resulting from the considerable angle of incidence of the light-rays on the cross-hairs?

Mr P. G. Mott dealing with a point raised by Mr Cuthbert on the use of air survey for large-scale plans, explained that the photogrammetrist overcame the difficulty of detail screened by station roofs and bridges, etc., by laying down markers before photography at specially selected points. Those markers showed up clearly on the air photographs and were later used by the ground parties to establish fixed lines from which the missing detail could be completed by simple offset measurements. With the aid of the markers and the large amount of detail which existed on a photogrammetric plan when it came from the plotting machine it was a comparatively simple matter for the ground surveyor to add the remainder, and such work could be carried out very rapidly.

He confirmed that, under present conditions photogrammetry could give a limiting accuracy of ± 4 to 6 inches on the ground. Greater co-ordinate precision than that could be obtained only by conventional methods of ground survey.

One point which did not appear to have been mentioned by the Author or in the discussion concerned the medium on which engineering surveys were plotted. Engineers were still inclined to adhere to the use of tracing linen and Whatman paper and the employment of cheap reproduction processes such as the so-called "true-to-scale" process, which was a complete misnomer. It often happened that the value of a survey carried out with great accuracy was completely vitiated in its subsequent use by the dimensionally unstable medium on which it was plotted and reproduced. That was quite unnecessary because there existed excellent proprietary media which had negligible distortion characteristics and, in addition, provided a better drawing surface with far greater transparency than any of the old-established materials.

It was true that a special problem arose in the case of railway plans which dealt with long sections of line involving a difficult storage problem. The present practice in that type of survey was to use rolls of Holland-backed Whatman paper, which was subject to considerable movement with changes of temperature and humidity. In the photogrammetric method that difficulty was partially offset at plotting stage by the fact that each stereogram was treated separately on four points of control, so that the error if it existed was not cumulative over a long strip. It was also customary to establish a very long line-scale after seasoning of the paper before use; it could be used to scale long distances on the plan and would expand on contact with the paper. Nevertheless, railway engineers would undoubtedly gain a better accuracy if a more stable medium could be found to meet their requirements.

Mr W. P. S. Cockle, speaking on the subject of railway surveys to large

scale, expressed the hope that those who were carrying out air surveys of that type would be able, within a few years, to provide a survey at 20 feet to the inch, which was what was really required; a 40-foot-to-the-inch survey was mainly of topographical value. Also the wisest plan was not, as had been suggested, to have a control traverse round the neighbouring streets, which was not the slightest use to the engineer and which the air-photography firms would not even bother to print on the survey which they provided, but to establish the control traverse down the railway itself. Between the important points, it was purely topographical and one worked to 40 feet to the inch, no calculations being involved; but when one came to bridges, railway stations, and junction work, one could enlarge that survey over short distances by the use of the tape to 8 feet to the inch or any larger scale desired, the whole being tied-in exactly to the aerial survey plotted at 40 feet to the inch. That had been done, and it seemed to be the only way to make an air survey of use to the civil engineer in the calculations required for alterations to existing railways.

*** **Mr T. Convey** referred to the early work of Dr B. A. Gould (in Cambridge, Massachusetts, 1875), followed by that of Professor A. A. Nicholson, J. E. Sears, and H. Barrell of the National Physical Laboratory, and others on the use of light-waves as standards of length. Later developments in that field had arisen from the investigations of Eric Bergstrand, in Norway, in the use of high-frequency light signalling, as referred to in the Paper. Could the Author indicate broadly the degree of progress which had been made in Great Britain so far.

The Author, in reply to the various questions that had not been answered during the discussion, said that Mr J. S. Clark of the Metrology Division of the N.P.L. was working on the standardization of tapes in terms of their electrical resistances and a Paper would be published in the next number of The Empire Survey Review (July 1953). In the meantime it could be stated that the Directorate of Colonial Surveys had borrowed the N.P.L. apparatus, which consisted of a piece of invar wire (of the same brand as the field tapes to be used) stretched on a wooden frame and connected across a Wheatstone Bridge. That piece of invar had been standardized by resistance methods at the N.P.L. and its resistance would be determined in the field at the time when the field tape was in use. It could be said that it was impracticable to determine the resistance of the field tape itself in the field satisfactorily, but a resistance thermometer made of the same material as the field tape would give a much closer result than any mercurial thermometer.

Concerning the accuracy of the geodimeter measurements, undoubtedly a very important controlling factor was the value taken for the velocity of light as compared with the true value in the atmospheric conditions at the time. That value depended upon the index of refraction for the particular

*** This contribution was submitted in writing upon the closure of the oral discussion.—Sec. I.C.E.

medium, which varied with the pressure, temperature, and, to a certain extent, the humidity of the air. Bergstrand claimed that errors of 1° C. in temperature, 3 millimetres of mercury in pressure, and 40 millimetres of mercury in humidity would each produce errors in the computed index of refraction of about 1 part in a million, and in his most recent determination of the velocity of the light he gave the m.s.e. of his value of μ as $\pm$ 0·000,000,2. Provided that the atmospheric conditions were recorded as carefully as conditions would permit, and their effects allowed for, errors in velocity due to small errors in deduced refractive indices would be negligible.

The Author had seen no mention in the published accounts of difficulties in alignment caused by the effect of flickering.

Mr Cuthbert had asked for more information on the manufacture of glass tubes for precise spirit-levels. Such information was not readily available in detail in standard text books on surveying and could be best obtained by a visit to one of the instrument makers. The glass tube was first placed on a bar and that bar was then bent to the necessary curvature, after which the grinding was done with an abrasive, by a reciprocating movement along the bar and a rotation about the axis of the glass tube. For very sensitive bubbles the grinding motion was done by hand, solely by rotating about the axis and not along it. Extreme care was then taken in cleaning the tube and filtering the liquid, before the final sealing off.

The question of the accuracy of radar altimetry surveys in conjunction with trimetrogon photography had been raised by Mr Chaplin. That combination was a particular case of small-scale survey that had been used in Canada, well outside the limits of engineering survey, for which the exceptionally wide cover of the trimetrogon cameras and the rapid and approximate results of the Airborne Profile Recorder were particularly suited, namely the production of the 1/1,000,000 Aeronautical Charts with contours at 500-foot vertical interval.

The A.P.R. was used particularly in Canada and the United States for making profile surveys for transmission lines, railway and road strip maps, and for radio link surveys. The electronic part of the apparatus (a parabolic antenna, on the underside of the aircraft, projected a narrow radar beam downwards, and the time of the return of the reflected beam was recorded), which was subject to the limitations already referred to, gave the depth of the ground profile below the aircraft and the value of such a record depended entirely upon knowing the height of the aircraft. Where no ground control existed that could be correlated with the accompanying photographic strips, that datum had to be barometric, the unknown fluctuations of which directly affected the accuracy of the whole method. Advantage was taken of the known relationship * of wind velocity, wind

* If v is the component of wind along the track, the slope of the pressure surface in the direction of the track is given by $\tan \alpha = \frac{2\omega \sin \phi \times v}{g}$ where w=angular velocity of the earth, ϕ=latitude, g= acceleration due to gravity.

direction, and the pressure contours, by recording the changes of drift angle of the aircraft, and applying a correction to the barometric datum. After such corrections had been applied and use had been made of any other control points, accuracies of $\pm$ 10 feet had been claimed in Canada.

Answers to questions dealing with the Zeiss Ni 2 level were tentative, but after a year of use in several tropical countries, no criticisms had been received on its lack of robustness or on difficulties arising from fluctuating temperatures. The wires of the compensator consisted of a magnetic non-rusting steel and all the light metals used in its construction were eloxadized.

The reply to Mr Convey's question was that work on the use of light waves as standards of length was being continued at the N.P.L. and reference had been made in the bibliography to Dr Essen's work in that connexion.

ELECTION OF ASSOCIATE MEMBERS

The following names were inadvertently omitted from the list of Associate Members, printed on pp. 308 and 309 in the Proceedings, Part I, May 1953, declared by the Council as having been duly elected at their meeting on the 17th February, 1953.

Home

Donald Tyson, M.Eng. (*Liverpool*).
Erik Docksey Walcot.
Robert Harry Wall, B.Sc. (Eng.) (*London*).
Michael Henry Waller, B.Sc. (*St Andrews*), Stud.I.C.E.
Owen Guiney Walsh, B.Sc. (*Durham*).
Emlyn Williams.
Thomas Peter Wilson, B.Eng. (*Liverpool*), Stud.I.C.E.

The Council at their meetings on the 17th March and the 21st April, 1953, in accordance with By-law 14, declared that the following had been duly elected as Associate Members :—

Home

Allen, Arthur Charles, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Anderson, Robert.
Anderson, Robert John, B.Eng. (*Liverpool*).
Arnold, Harry Kent, Ph.D., B.Sc. (*Birmingham*).
Aruliah, Taninayagam Arulanandam.
Atwell, Jack Herbert, B.Sc. (*Bristol*), Stud.I.C.E.
Backhouse, Roy Samuel, Stud.I.C.E.
Bannatyne, William, B.Sc. (*Glasgow*), Grad.I.C.E.
Barker, Derek Fletcher, B.Sc. (Eng.) (*London*).
Barnes, Charles Ilderton.
Barras, Harold Wilmot.
Barratt, Robert Nigel, M.A. (*Cantab.*), Stud.I.C.E.
Bell, Graham Fraser.
Bolton, Malcolm Dennis, Stud. I.C.E.
Boyce, Albert Stanley.
Boydell, Peter Glover, B.Sc.Tech. (*Manchester*), Stud.I.C.E.
Brayshaw, Christopher Neave, B.Sc. (*Manchester*).
Brewington, Charles Bernard, B.Sc. (*Birmingham*).
Burch, Robert Henry.
Burrill, Norman Edward, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Buxton, William Theodore, B.Sc. Tech. (*Manchester*).
Cameron, Thomas Alexander, B.Sc. (*Belfast*).
Campbell, Howard Hindmarch, B.A. (*Cantab.*).
Channon, Michael Townsley, M.A. (*Cantab.*).
Cliffe, Arthur Philip, B.Sc. (*Manchester*).
Codd, John Thomas, Grad.I.C.E.
Costain, Adrian Kenneth Arbory.
Cowley, Walter Richard.
Cowlin, Charles Robert, M.A. (*Cantab.*), Grad.I.C.E.
Cramp, Geoffrey.
Creet, John George, B.Sc. (Eng.) (*London*).
Cruickshank, Harvey Alexander, B.Sc. (*Edinburgh*).
Culley, Ivan, B.Sc. (Eng.) (*London*).
Dalrymple, William James, B.A. (*Cantab.*).
Dennis, Norman George, B.A. (*Cantab.*).
Diamant, Herbert Heinz, B.Sc. (Eng.) (*London*).
Dodridge, Gerald Arthur.
Dodwell, Oscar John, B.Sc. (Eng.) (*London*).
Duncan, Archibald Mackinnon, Stud. I.C.E.
Dyne, Walter Charles.
Evenett, Howard James, B.Sc. (Eng.) (*London*).

Field, Derek Harold, M.A. (*Cantab.*).
Freeman, Colin Thomas, M.A. (*Cantab.*).
Gauld, Forbes Fraser, B.Sc. (*Aberdeen*), Stud.I.C.E.
Gaynor, Montague, B.Sc. (Eng.) (*London*), Grad.I.C.E.
Gibbs, David Stormont, M.A. (*Cantab.*), Stud.I.C.E.
Gibson, David, B.Sc. (*Glasgow*).
Gibson, William, B.Sc. (Eng.) (*London*).
Glaister, Thomas Vernon, B.Sc. (*Durham*).
Goddard, Dennis Frederick Charles, Stud.I.C.E.
Goldes, Anton Abe, B.Sc. (*Witwatersrand*).
Gould, Harry Bernard.
Gracey, Gilbert Crewdson, B.Sc. (*Leeds*).
Hardy, Barry Edleston, Grad.I.C.E.
Harker, Bernard Gregory.
Harrison, Thomas Andrew, B.Sc. (*Belfast*).
Hayward, George Victor, B.Sc. (*Birmingham*).
Henry, John Martin, B.E. (*National*).
Higgins, Kieran, B.Sc. (*Belfast*), Stud.I.C.E.
Hill, John William, B.A., B.A.I. (*Dublin*).
Horsfield, John, M.A. (*Cantab.*).
Houston. John Arthur MacDonald.
Hudspeth, Donald Sydney, B.Sc. (Eng.) (*London*), Grad.I.C.E.
Hughes, Thomas Alun, B.Sc. (*Wales*).
Jared, Dennis Edward, Grad.I.C.E.
Jeffrey, Neil McLeod, B.Sc. (*Glasgow*).
Jones, James Edward Eric, B.Sc. (Eng.) (*London*).
Kenyon, Percy, B.Sc. (*Manchester*).
Kingston, James Harold, B.A., B.A.I. (*Dublin*).
Koronski, Karol Kurt.
Latta, James Kenneth, B.Eng. (*Liverpool*).
Ledson, Kenneth Manley, B.Sc. (*Manchester*), Grad.I.C.E.
Lewin, Jacob.
Liyanage, Mohan Shantilal.
Llanwarne, Donald George.
Lomas, John Leslie Venables, B.Sc. Tech. (*Manchester*), Grad.I.C.E.
Lovejoy, Edward Geoffrey, Stud. I.C.E.
Lowe, John Robert, B.Sc. (Eng.) (*London*).
Lowe, Sidney Arthur, B.Sc. (*Wales*).
McEwen, Ian, B.Sc. (Eng.) (*London*).
MacGillivray, Andrew.
McKechnie, Archibald Lamont.
Maclean, Charles Dettmar, B.Sc. (*Edinburgh*).
Mahony, John Patrick, B.Sc. (*Edinburgh*).
Mander, Reginald Graham, B.Sc. (*Bristol*).
Mapstone, Frederick Walter Thomas James, Grad.I.C.E.
Marsh, Alan Wingrove.
Mather, Stanley Emmanuel Jeyanesan.
Miles, Norman Edward, B.Sc. (*Wales*).
Miles, William John Edward, B.Sc. (*Durham*).
Miller, William Beatty Smith, B.A. (*Cantab.*).
Mockridge, Philip James Nicholas, B.Sc. (Eng.) (*London*).
Monahan, Alfred, B.A., B.A.I. (*Dublin*).
Munson, Herbert Douglas, B.Sc. (Eng.) (*London*).
Nicholson, Robert Nicholas, B.Eng. (*Liverpool*).
Nielsen, David Swallow.
Odunsi, Zacchaeus Adedeji, B.Sc. (Eng.) (*London*).
Osborn, Harry Dennis.
Page, Frank Arthur, B.Sc. (Eng.) (*London*).
Peach, John Randall, M.Eng. (*Liverpool*).
Pearsall, Richard Devenish, B.A. (*Cantab.*).
Peel, Edward Emery, B.Sc. (*Durham*).
Pepper, Roy Arthur, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Petersen, Bjarne.
Phillips, Richard Vivian Clive, M.C., B.A. (*Cantab.*).
Picknett, John Kay, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Pope, Harry Martin, B.Sc. (*Wales*).
Porter, John Priestley, B.Sc. (Eng.) (*London*).
Rees, Dewi Ceidrych, B.Sc. (*Wales*).
Rhodes, Kenneth, B.Sc. (*Leeds*).
Rippon, Stanley Richard, B.Sc. (*St Andrews*).
Robinson, Thomas, B.Sc. (Eng.) (*London*).
Robinson, Thomas Algie.
Rooney, Joseph James, B.Sc. (*Belfast*).
Russell, Ernest Robert, B.Sc. (*Glasgow*).
Russell, Frank Herbert, B.Sc. (Eng.) (*London*).
Ruxton, Thomas David, M.A. (*Cantab.*), Stud.I.C.E.
Samarawickrema, Thompson Bernard Pallewela, B.Eng.Sc. (*Melbourne*).
Sanderson, Francis Oliver.
Semple, Norman George, B.Sc. (*Glasgow*), Stud.I.C.E.

Shewell, Hugh Morland, B.Sc. (*Birmingham*).
Shiner, Norman Walter, B.Sc. (Eng.) (*London*).
Sidney-Smith, Patrick Speoule, B.Sc. (*Belfast*).
Sims, Henry Evan Bernard, B.Sc. (*Wales*).
Skinner, Ernest Geoffrey, B.Sc. (*Leeds*).
Smith, Anthony Peter, B.Sc. (*Birmingham*).
Smith, James Ogilvy, B.Sc. (*Edinburgh*), Stud.I.C.E.
Smith, Robert.
Stewart, Kenneth John.
Stewart, Robert Wilson, B.Sc. (*Glasgow*).
Stott, Peter Frank, M.A. (*Cantab.*), Stud.I.C.E.
Stringer, Robert George Alexander.
Szymkiewicz, Victor.
Tetlow, Edward Alan, B.Sc. (Eng.) (*London*).
Thornton, David, B.A., B.A.I. (*Dublin*), Stud.I.C.E.
Thornton, Paul Rosslyn.
Thorpe, Kenneth Edgar.
Tough, Stephen George, B.Sc. (*St Andrews*).
Townson, John Kenneth, B.Sc. (*Manchester*).
Trewin, Allan Mortimer.
Tucker, Francis Anthony Joseph.
Walden, Kenneth Owen, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Waterhouse, James, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Watkins, Vivian Holmes, B.Sc. (*Wales*).
Webb, Brian Harry, B.Sc. (*Birmingham*).
Weir, Robert.
Westnidge, Wilfred Richard, B.Sc. (Eng.) (*London*).
Wilson, John, B.Sc. (*Belfast*).
Wood, Ernest James, B.Sc. (Eng.) (*London*).
Wooderson, Edwin Howard Huntley, B.Sc. (Eng.) (*London*).
Woulfe, John Maurice, B.A., B.A.I. (*Dublin*).
Wright, Peter, B.Sc. (Eng.) (*London*).

Abroad

Allen, Leonard, Stud.I.C.E.
Beal, Patrick Allen Heathcote, B.Sc. (Eng.) (*London*).
Bishop, Roland Geddes, B.E. (*New Zealand*).
Carruthers, John, Grad.I.C.E.
Fickling, Hugh Condra, B.A. (*Cantab.*).
Green, William Robert.
Grigg, Herbert Arthur.
Harborne, Roger John, B.Sc. (*Bristol*).
Hunt, Cedric Geoffrey.
Kerr-Hislop, Walter Barrie, B.E. (*New Zealand*), Stud.I.C.E.
Lindley, Marie (*Miss*), B.A. (*Cantab.*), Stud.I.C.E.
Moncrieff, Malcolm Lawrence Anderson, B.Sc. (Eng.) (*London*), Stud.I.C.E.
Newton, Raymond Harold.
Orman, Kenneth Gerald, D.F.C.
Payne, William Gordon.
Stern, Peter Henry, B.A. (*Cantab.*).
Wilkins, Leonard Frank, B.Sc. (Eng.) (*London*), Stud.I.C.E.

DEATHS

It is with deep regret that intimation of the following deaths has been received.

Members

Sir David Anderson, LL.D., B.Sc. (Past-President) (E. 1906, T. 1915).
Raymond George Hubert Clements (E. 1908, T. 1925).
Daniel Peter Howells (E. 1907, T. 1921).
Sigvald Johannesson, D.Eng. (E. 1929).
Arthur John Whyte McIntosh, B.Sc. (E. 1929, T. 1944).
Harry Powell Miles, O.B.E. (E. 1896, T. 1902).
John Hall Rider (E. 1896, T. 1902).
Guthlac Wilson, S.M., D.Sc. (Eng.) (Member of Council) (E. 1928, T. 1938).

Associate Members

John Elder Duncan, B.Sc. (Eng.) (E. 1924).
Wilfred Hall, M.A. (E. 1900).
Frederick William Hey (E. 1916).
Sidney Land Luker, B.Sc. (E. 1918).
Thomas Lunt (E. 1920).
Edwin McQueen (E. 1924).
Louis Samuel Rolf Mangénie, B.Sc. (E. 1931).
John Alexander Rennie (E. 1913).
Thomas Reader Smith (E. 1888).
Percy George Spary, B.Sc. (Eng.), B.Eng. (E. 1921).
James Walmsley, B.A. (E. 1913).

Associate

Charlie Roland Woods, M.B.E. (E. 1938).

Student

William Paterson Hunter, B.Sc. (A. 1946).

JOINT MEETING

THE INSTITUTION OF CIVIL ENGINEERS
THE INSTITUTION OF MECHANICAL ENGINEERS
THE INSTITUTION OF ELECTRICAL ENGINEERS

Held at the Institution of Civil Engineers

Friday, 10 April, 1953

COLONEL B. H. LEESON, C.B.E., T.D., President I.E.E., in the Chair

A Paper entitled:

" The Athlone Fellowship Scheme for the Practical Training in Industry of Canadian Engineering Graduates in Great Britain "

by

W. Abbott, C.M.G., O.B.E., Ph.D., B.Sc.(Eng.), M.I.Mech.E.

was presented for discussion. The following is a summary of the Paper.*

The Athlone Fellowship Scheme is designed to provide post-graduate studies in engineering in Great Britain for thirty-eight Canadian graduates each year. The Fellowships have a duration of two years and are tenable in industry, in universities, or partly in each.

From the inception of the scheme, the Author has assisted in the selection of the graduates in Canada and arranged for their location and training in the United Kingdom.

Inauguration of the Scheme arose from a realization of the need for redressing the divergence of the trade balance between Canada and Britain on the one hand and Canada and the United States on the other. Lack of knowledge of British industrial potential seemed to be one of the major reasons for that divergence.

There are two classes of award: Group A, for those about to graduate; and Group B for those already graduated and at work. Group A awards are on a quota basis as follows: Nova Scotia Technical College, 2; University of New Brunswick, 1; Laval University, 2; McGill University, 3; Ecole Polytechnique, 2; Queen's University, 3; University of Toronto,

* The full text of the Paper and discussion will be published by the Institution of Mechanical Engineers and the Institution of Electrical Engineers.

5 ; University of Manitoba, 2 ; University of Saskatchewan, 2 ; University of Alberta, 2 ; and University of British Columbia, 4.

The Paper analyses the many factors influencing the operation of the scheme in Canada. Such factors include : the increased emphasis on works training ; the greater " higher-degree consciousness " in the North American continent ; the variety of graduate courses available ; the lack of knowledge among Canadians of the United Kingdom ; and, probably the most important single factor operating against the scheme, the intense demand in North America for graduates in all branches of engineering and the high initial salaries offered to them. The last has recently had a far-reaching effect on the response to the scheme and, as Table 1 confirms, the Fellowships are becoming more attractive to those who wish to enter research fields in which, in any case, a higher degree is essential.

TABLE 1

	Year	
	1951–52	1952–53
Number opting for university training	12	18
Number opting for industrial training	12	9
Number opting for mixed university and industrial training	14	11
Branches of engineering in which the Fellows have graduated :—		
Civil	4	9
Mechanical	8	9
Electrical	7	3
Aeronautical	2	2
Chemical	4	2
Metallurgical	3	—
Mining	1	1
Petroleum technology	—	3
Engineering physics (includes thermionics)	6	9
Engineering business	3	—
Totals	38	38

The Author emphasizes that much of the success of the Scheme will depend upon the attitude of the people with whom the students come into contact whilst in Britain.

The following took part in the discussion :—

Professors D. G. Christopherson, A. J. S. Pippard, and Andrew Robertson; and Messrs. R. E. Collin, K. R. Evans, H. J. B. Harding, A. T. Holman, G. Knott, H. M. Lacey, R. U. Law, F. R. Livock, F. H. Perkins, R. J. S. Pigott, A. S. Quartermaine, J. Y. Rousseau, F. Slingerland, N. G. Treloar, and R. M. Wynne-Edwards.

Paper No. 5895

"The Control of Concrete Quality"

by

Leonard John Murdock, M.Sc.(Eng.), Ph.D., A.M.I.C.E.

(*Ordered by the Council to be published with written discussion*) †

SYNOPSIS

The control of concrete quality demands attention not only to the choice of materials and their proportioning and mixing, but to the multitude of details involved in the many aspects of placing, consolidation, finishing, and other processes. The best results are achieved when the contractor, the design engineer, and the technologist combine to ensure that the right materials and techniques are employed. Methods of achieving effective quality control on the site are outlined, and a survey is made of some of the more important requirements for the production of a uniformly satisfactory standard.

The value of tests on concrete cubes as a means of control is discussed. Analyses are made of the strengths of test cubes produced on a number of sites, which indicate the variation to be expected under different site conditions and with control measures of varying effectiveness. It is shown that good control and accurate proportioning of the materials is important. Weigh-batching is an advantage, but only when coupled with good control and careful maintenance.

Although statistical analyses are valuable in assessing the variation in concrete cube strengths to be expected under various site conditions, they are of very little value for day-to-day control, owing to the small number of cubes which it is usual to test, and other factors. Cube strengths are, however, a useful guide and the control measures should be such as to ensure that they are kept within the anticipated range above and below the average strength.

Introduction

The use of concrete is so universal, ranging from the production of a few cubic yards for such items as lintels on a building site, to the construction of great dams requiring millions of cubic yards of concrete subject to rigid technical control, that any method of achieving control of its quality must have infinite flexibility.

Early efforts at improvement in quality were mainly concerned with reductions in the water/cement ratio to improve strength, durability, impermeability, frost resistance, wear resistance, and other desirable properties. It was not only necessary to educate the workmen in the placing and consolidation of a stiffer material which did not flow into place so easily, but also to persuade many civil engineers that the water/cement

† Correspondence on this Paper should be received at the Institution by the 15th November, 1953, and will be published in Part I of the Proceedings. Contributions should be limited to about 1,200 words.—Sec. I.C.E.

ratio was of importance. Even now it is probable that this is not everywhere fully appreciated or understood. Improvements in machinery were, and still are, necessary to cope with the stiffer concrete being produced.

In the past few years attention has become directed more to the production of uniform concrete of predetermined strength, and it is now possible by modern methods to produce consistently good results to suit the designers' requirements. This is of particular importance in connexion with prestressed concrete, which relies so much on the consistent attainment of crushing strengths which would have been considered impracticable 20 years ago.

Weigh-batching of the aggregates as well as of the cement, which is now superseding volume batching, even where the quantities of concrete produced are quite small, can, with proper care, aid considerably in making concrete of uniform quality. Not only are the properties of the hardened concrete more consistent, but because of the greater uniformity of the wet concrete, other operations, such as placing and consolidation, are facilitated, and such troubles as honeycombing and the formation of stone pockets become less frequent. However, control of all the operations from the selection and production of materials to the finishing and curing of the concrete is essential to the construction of a high-class structure. This is a matter for co-operation between all concerned.

The complexity of the work makes it necessary to adopt a wide variety of methods of approach to achieve improvements in quality and flexibility of control, and to cope with works of greatly varying size being carried out under a wide range of conditions.

Organization of Quality Control

The quality control of concrete should aim at producing a uniform material which provides those properties particularly desirable for the work envisaged. At the same time, a careful balance must be maintained to ensure that the quality of concrete is satisfactory for the purpose, without being of unnecessarily high strength, the achievement of which inevitably results in a marked increase in cost. Thus, lean mixes of low strength are usually adequate for mass concrete in foundations and in the cores of dams where, in fact, they are advantageous because the heat generated during hydration is less than that for richer mixes. On the other hand, concrete pipes and haunchings used in sulphate-bearing ground must be of rich dense mixes if rapid and costly failures are to be avoided.

The choice of plant and procedures may have a considerable influence on the results achieved, and if effective quality control is to be obtained, discussions between the design engineer and the contractor should be arranged at the planning stage. From this point the details of control can be developed.

It is fortunate that most of the desirable properties of concrete are

enhanced by increasing the compressive strength, and this, therefore, affords a simple measure of the general standard of quality. It should be noted, however, that it is not only necessary to control the quality of the concrete at the mixer, but to provide experienced supervision of all the processes which follow. This cannot be a matter for individual effort only, and any measures envisaged for the control of concrete quality must provide for co-operation and general instruction in good or improved techniques, and in the use of tools and machinery. It is essential that the educational methods should be such that their influence is apparent from the site agent down to each operative involved.

In order to achieve good results, it is necessary to adopt several methods of approach, such as :—

(1) Direct control by means of a concrete engineer, and assistants, if necessary, specially trained in the work and resident on the site, where the quantity of concrete is large, or for some special reason an unusually high standard of concrete quality is desired. This concrete engineer may be backed by a site laboratory. He should be responsible not only for the production of good quality concrete at the mixer, but for supervision of the many operations which ensue.

(2) Instructions and advice on the site, on both specific and general questions, by a visiting engineer with wide experience of concrete technology. This form of approach is particularly valuable on the smaller sites, provided the concrete engineer is prepared to talk to the site staff, foreman, and gangers in non-technical language which they can understand.

(3) Education of site staffs by means of pamphlets dealing with concreting technique, copies of technical Papers and encouragement to attend any meetings at which they can join in discussions on concrete technology.

(4) Testing of materials and concrete by experienced laboratory engineers. The emphasis on experience is important, since the observations made during testing and the interpretation of the results are just as important as the figures obtained from the testing machine.

Emphasis has been placed on the need for engineers trained in concrete technology, for without them, effective quality control is not possible, and greater facilities for training in this subject in the universities and technical colleges are urgently required.

Workmanship

In any construction in concrete, much reliance is placed on the foreman, gangers, and workmen themselves, and it is essential that at least the key

men should have adequate training. The key men, apart from the foreman, may be considered as the mixer driver, the carpenter, the steel fixer, and the placing ganger. The mixer driver should not, as so often happens, be a labourer picked out on the site because he is a little more mechanically minded than the rest. Both he and the placing ganger should be men who have had experience in concrete making, and who are kept continuously on this particular work travelling from one site to another.

Aggregates

The economic production of all concrete depends on the use of local supplies of aggregate and this is, therefore, one of the first items requiring consideration when concrete construction is envisaged. Any investigation of aggregate supplies should commence with a visit to the pit or quarry in order to inspect the conditions at the working face, the type of equipment in use and its standard of maintenance, and to obtain representative samples for testing. The object of such visits is mainly to assess the chances of obtaining an adequate supply of aggregate of uniform quality.

The testing of aggregates for their suitability for concrete, the influence of grading on the workability of the concrete produced, the avoidance of segregation, and the design of suitable mixes have been dealt with by the Author elsewhere.[1, 2] Various other Papers on this subject [3, 4, 5, 6] are also available.

Measures to be taken on the site include a visual checking of all aggregates delivered and the taking of samples for testing at frequent intervals. In order to prevent mixing on the site, some form of partitioning of stockpiles behind the mixer is strongly recommended. Adequate drainage of stockpiles is an advantage in that the more uniform moisture content which results facilitates control of the water/cement ratio. If the aggregate is deposited straight on to the ground it is advisable not to use the bottom foot or so, which not only acts as a drainage layer, but enables the mixing gang to avoid the inclusion of soil.

Other measures necessary on the site, including suggestions for the prevention of segregation of aggregate in large stockpiles, have been described elsewhere.[2, 3]

In hot desert areas, shading and wetting down are of considerable benefit, and protection from blown dust should be provided.

On many of the larger projects in the United States, not only is the coarse aggregate re-screened at the batching plant, but the sand is separated by classifiers into two or three grades which are re-combined to give the required grading.

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[1] The references are given on p. 445.

Cement

The quality of cement is usually accepted as being satisfactory and it is certainly usual to find that site troubles derive from other factors. If, however, a series of low strengths are recorded, or there is premature stiffening or unusual delay in setting, investigations should be made. These normally involve sending samples of the cement to a properly equipped testing laboratory.

An indication of the extent of the variations which occur in the crushing strength of vibrated mortar cubes made in accordance with B.S. 12 : 1947, is given in Table 1 (see Appendix). It appears that when a reasonably large number of samples are tested, a variation of $\pm$ 20 to $\pm$ 33 per cent from the average may be expected, depending on the source of supply. Similar variations have also been recorded by investigators in other countries, including Wing and Ruettgers.[8]

The use of special cements, such as sulphate-resisting cement, low-heat cement, and high-alumina cement, cannot adequately be discussed in this Paper. It is important to remember, however, that the strength of high-alumina-cement concrete is reduced by about half as soon as its temperature rises above 80–90° F. Hot cement, so often the cause of controversy on the site, is not likely to be in any way detrimental, except in hot weather.

Proportioning of Materials

The accurate proportioning of the aggregate and cement by means of weigh-batching has already been mentioned in the Introduction as making an important contribution in producing concrete of uniform quality, and this applies even where the quantities of concrete to be produced are relatively small. It is, however, essential that the weighing machines used on the site should be properly maintained and their accuracy checked at frequent intervals.[9] Without thorough and frequent maintenance, weigh-batching machines may lose their accuracy and provide no more uniformity than is possible by volume-batching.

Weighing errors are apt to occur when knife-edges or other moving parts become clogged or damaged, levers or links become bent and bind on some part of the framework, dash-pot damping devices become detached or are filled with the wrong type of oil or water, movement occurs in counter-balances, and, in the case of the spring-balance type of mechanism, if a spring should break or even if the transparent plastic front warps so that the pointer rubs against it during rotation.

Where large quantities of concrete are to be produced, central batching plants are usually erected and are provided with manually operated or semi-automatic weighing machines under the storage hoppers, both for the aggregate and the cement. A typical example is given in *Fig. 1*. With this arrangement it is usual to provide a small field laboratory, and an

Fig. 1

CONCRETE BATCHING AND MIXING PLANT AS USED AT LONDON AIRPORT

Fig. 2

SMALL CEMENT WEIGHER FOR USE WITH BULK CEMENT

Note crossed spring-steel tapes used as fulcrum, and suspension from moving carriage to allow tipping directly into the loading hopper of the mixer.

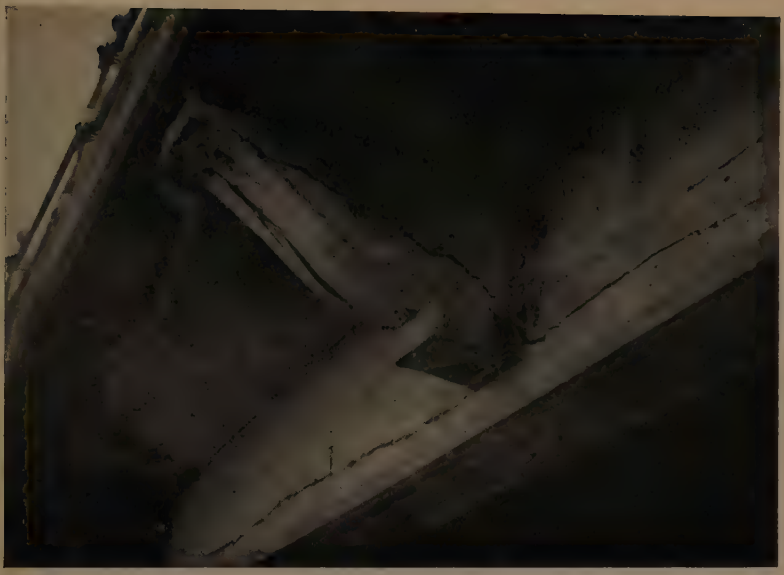
Fig. 3

HONEYCOMBING CAUSED BY UNEVEN MIXING OF AN UNDERSANDED MIX
Note also the unsatisfactory sloping pour.

Fig. 4

HONEYCOMBING IN PRESTRESSED CONCRETE CONSTRUCTION
This is caused by the inclusion of one or more undersanded batches. Note also the evidence of the sloping pour planes that the concrete was placed at one point and allowed to flow along the shuttering.

Fig. 6



FAILURE OF A BEAM AND CORBEL SUPPORTING A SEASIDE PROMENADE

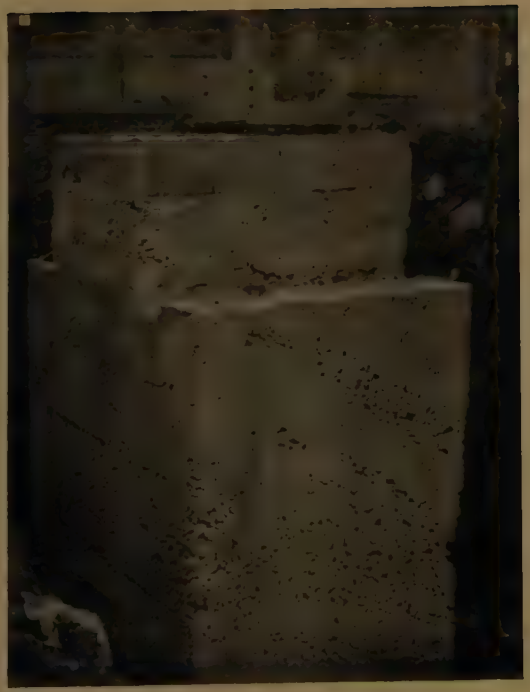
Failure was caused by lack of adequate cover to the reinforcement, resulting in rusting, expansion, and spalling of the concrete.

Fig. 7

HONEYCOMBING RESULTING FROM SEGREGATION

Concrete was allowed to flow along the shuttering, passing over a stop end on the left. This is part of a large retaining wall in an exposed whinstone finish, the blemishes shown being repeated at several points along the length.

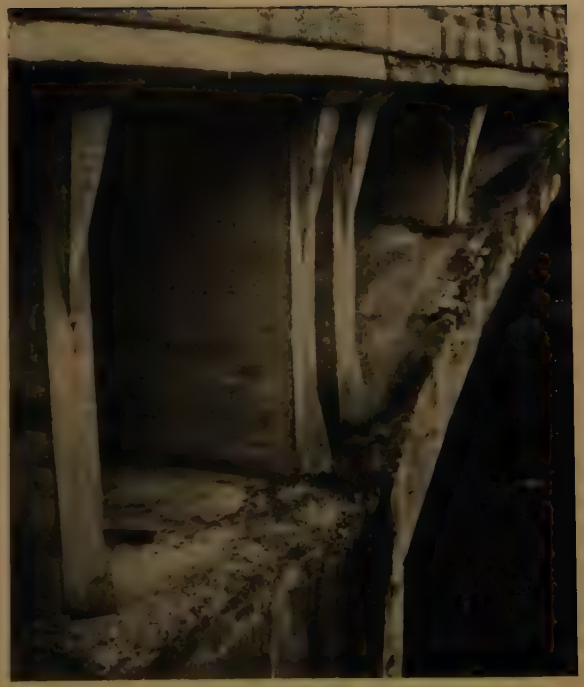
Fig. 8



SURFACE HONEYCOMBING ON A LARGE COLUMN BASE

Placing was by tipping from the top. A cone formed in the centre, down which the stones rolled to the face.

Fig. 9



FAILURE OF OVER-WET CONCRETE IN A BRIDGE

Failure was caused by frost action. With a water/cement ratio below 0·6 this would not have happened.

inspector whose duties are to calibrate the weighing machines at frequent intervals, to check the quantities of material supplies against the quantity of concrete produced, to check the quality of the aggregate delivered, and its moisture content when used, and to take samples of the concrete produced for testing. Many civil engineers now consider that the most effective control of concrete quality is obtained by placing this inspector permanently at each mixer.

The weighing of cement usually provides more difficulty than that of aggregate, mainly because it is difficult to obtain a uniform flow, and compressed-air assistance is often needed to overcome arching in the valve opening. When it is appreciated that the normal rate of flow in a large weighing machine is about 50 lb. per second, it will be realized that any sudden rush, when the quantity in the weigh-bucket is near the correct weight, may result in some excess which will be reflected either in increased workability or in increased strength for the particular batch. Another difficulty which arises in weighing cement is the tendency to build-up in the weighing hopper, particularly when the atmosphere is damp.

Central batching with special trucks to transport the batched materials to a mixer placed near the forms is not so common in Great Britain as in the U.S.A., although it provides ease of control, and a marked reduction in the contamination and wastage of aggregate and cement which so often occurs with small stockpiles of material at scattered points.

On small sites, where mixers of the 7- and 10-cubic-foot type are in use, small weighing machines are available, and providing they are well maintained, have proved to be quite successful.

On small sites it is usually easier to adjust the size of the mix to suit a 1-cwt bag of cement as delivered. This is a reasonably accurate method, although check weighing of cement in bags has indicated a variation from less than 100 lb. to more than 120 lb. in individual bags of cement. With the shortage of paper bags, attempts are now being made to provide for bulk delivery of cement, even on small works. If such bulk delivery is accepted, the cement should always be weighed, and a separate weighing machine should be used from that provided for the aggregate. If cement and aggregate are weighed together, the dampness from the aggregate causes a serious build-up of cement mortar in the weighing hopper, which measurements have shown to amount to 1 cwt or more in a matter of ten batches, even when some shaking is applied to the hopper to hasten discharge. A simple weighing machine, in which a new type of fulcrum devized by the Author utilizes four crossed spring-steel tapes to overcome the disadvantages of knife edges or ball races, is shown in *Fig. 2.* The resistance to turning of this fulcrum is negligible, and is in any case constant.

Analyses of the crushing strength of cubes made on a number of sites in Great Britain are given in Tables 2 to 7 (see Appendix), and indicate that whilst uniform concrete does not automatically result when weigh-batching is adopted, the variation in strength is less than that generally

obtained with volume-batching. Some of the variations undoubtedly show a lack of control largely attributable to a lack of attention to correct proportioning of the cement and aggregate.

With given proportions of aggregate and cement, the water/cement ratio is determined by the workability required for satisfactory placing. With the workability controlled by close observation at the mixer, so that any variation is small, it may be taken that any changes in the water/cement ratio will also be small and the strength of the concrete will be reasonably uniform. Further control may be obtained by making tests on the moisture content of the aggregate, particularly the sand, at frequent intervals, and adjusting the quantity of water added at the mixer accordingly. Except where large stockpiles of aggregate are maintained, however, the variations in moisture content of the sand from one load to another, and from one part to another of a small stockpile, make the value of tests for moisture content doubtful. The cost of making such tests continually is, in any case, excessive when small quantities of concrete only are to be produced, and under these conditions it is suggested that the following measures be adopted in order to secure concrete of the required quality.

The first few batches of concrete should be produced under the supervision of an experienced engineer or inspector, the aggregate and sand being carefully weighed and checked for surface and absorbed moisture content. When the aggregate is saturated the absorbed moisture may be taken as constant and should not be included in the water/cement ratio. The surface moisture will be variable and should be deducted from the theoretical quantity of water required when determining the water to be added at the mixer. If the aggregate is dry, it will be necessary to determine the quantity of water absorbed in bringing the aggregate to a saturated surface-dry condition, and to add this additional water to the theoretical quantity required. In the tropics it is advisable to keep the aggregate wet, if an ample supply of clean water is available.

This correctly proportioned batch is then mixed, the workability checked by means of a slump test, or compacting-factor apparatus, and cubes made for crushing-strength tests. The appearance of the mix should be particularly noted and should be observed by the mixer driver and the placing ganger. This concrete should then be placed and observations made on its suitability for placing in the formwork, on ease of consolidation, and on any tendency to segregate. If the concrete is found to be satisfactory in all respects, the mixer driver and the placing ganger should be instructed that all further concrete produced should have a similar appearance.

Checks should be made by the engineer or inspector from time to time, especially if undue variation occurs in the routine cube tests. The engineer or inspector may be responsible for a number of sites, visiting them in turn.

Mixing

Several types of concrete-mixer are available, but the commonest type seen on sites in Great Britain is the non-tilting drum. This type of mixer is, unfortunately, not particularly efficient when stiff or dry mixes are being produced. Its disadvantages lie in the building-up or sticking of material in the mixer and its inability to effect a positive transfer of material between the two ends of the drum. Sticking or build-up can sometimes be minimized by adjustment to the mixer blades, even to the extent of omitting some of them.

Uniformity of mixing is improved by a certain amount of pre-mixing during batching and transfer to the mixer loading skip. If there is an apparent difference in consistency between the concrete first discharged and that at the end of discharge, trials should be made with a different order of placing of the materials in the loading skip.

With most mixers it will be found that filling the loading hopper in more or less horizontal layers of gravel, cement, and sand, possibly with another layer of a different size of gravel on top, provides the best conditions.[10, 11] The piling-up of any one size of material in the throat of the loading skip should be avoided. Blanks [12] states that with large mixers (4-cubic-yard) the sequence of materials into the mixer is of extreme importance. The addition of all the water before the other materials sometimes reduces the sticking of mortar, but there is a risk of slopping.

For dry mixes, the rotating pan with stirrer and the paddle type give better results. These mixers are, however, cumbersome in the larger sizes and more costly than the rotating-drum type. Tilting-drum mixers are sometimes used, but are usually seen in the smaller sizes only.

The maintenance of the mixer in good condition, including the water supply system, is essential to the production of good concrete.[10, 11] Any decrease in the speed of rotation of the drum lowers the efficiency of mixing and this point should be checked at regular intervals. Overloading of the mixer also gives unsatisfactory results, and the size of the batch should never exceed that for which the mixer has been designed. Leaking valves on the water system result in variations in the water/cement ratio, according to the length of time the mix remains in the drum.

There is a need for an improved type of mixer for site use, capable of producing more-uniform concrete than that given by the rotating-drum mixer.

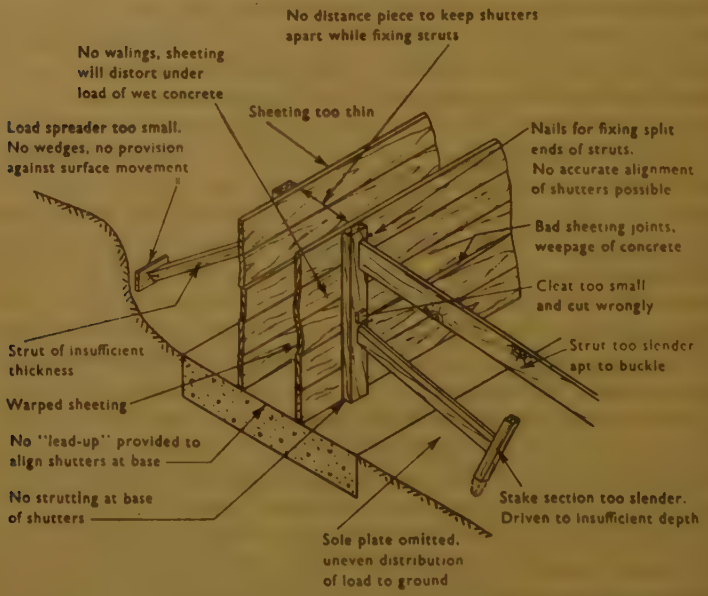
Shuttering

Considering that the cost of shuttering to a concrete structure is often one-third, or even more, of that of the whole work, it is surprising that its design and erection are so often left entirely to the foreman carpenter on the job. This may not apply on the larger and more important structures,

but even with these, it is common to leave much of the detail to an engineer on the site who may not have had very much experience in shutter design, and there are very few concrete constructions which are not marred at some point by trouble with the shuttering, especially slipping. This slipping may be caused not only by inadequate design, but also by errors or omissions in erection on the site, and the importance of inspection to ensure that the shuttering is satisfactory cannot be over-emphasized.

The design of shuttering must be related to the method of placing the concrete, the anticipated rate of placing, the consistency and proportions

Fig. 5


No distance piece to keep shutters apart while fixing struts
No walings, sheeting will distort under load of wet concrete
Sheeting too thin
Load spreader too small. No wedges, no provision against surface movement
Nails for fixing split ends of struts. No accurate alignment of shutters possible
Bad sheeting joints, weepage of concrete
Cleat too small and cut wrongly
Strut too slender apt to buckle
Strut of insufficient thickness
Warped sheeting
No "lead-up" provided to align shutters at base
No strutting at base of shutters
Stake section too slender. Driven to insufficient depth
Sole plate omitted, uneven distribution of load to ground

FAULTS IN SHUTTER ERECTION.

of the mix, the temperature of the concrete, and the properties of the cement. A summary of existing knowledge on the influence of these variables on the lateral pressure of concrete against forms has recently been published.[13]

A few errors which are commonly seen, particularly on small concrete works are illustrated in *Fig. 5*. Other items also result in movement, such as the omission of washers under the bolt heads (with the result that under the concrete pressure the bolt head becomes embedded in the wet timber), the use of wedges with too steep an angle, or wedges which are driven between badly cut timbers, and the loosening of members by vibration when this method of consolidation is adopted.

Slipping, movement, or bending of shuttering, whether in steel or timber, usually results in a serious loss of fines; leaving honeycombed patches. Further, the bulge which occurs is unsightly and very difficult to hide without cutting back the concrete to some depth, re-shuttering, and providing a new face. Shuttering for visible concrete surfaces should always be constructed to some design which presents a regular pattern, especially where vertical and horizontal joints occur.

Some care is necessary in using steel shuttering, in that the lift for which it has been designed may only be applicable if the rate of placing is slow. Failures of standard panel units through lack of appreciation of this point are not uncommon.

Reinforcement

Reinforced-concrete designs normally follow the recommendations of the Code of Practice with regard to the cover required on the reinforcement. There must, however, be manufacturing tolerances, particularly on the larger and more intricate bars, and the cover given in the Code of Practice should be regarded as the minimum and not an average value. Otherwise there is a danger that in some places the reinforcement may be too near the surface, with the risk of serious failure such as that shown in *Fig. 6*, where cracks have opened along the lines of the reinforcement owing to the expansion which occurs as corrosion proceeds.

Spacer pieces and other devices are available as an aid in maintaining the proper cover to the reinforcing bars. These spacers must be impervious in themselves and not pieces of highly absorptive mortar.

Preparation for Concreting

Where a bond is required between the new concrete and that previously placed, the final surface to receive the new concrete should be dense, free from laitance, and clean. Methods which are adopted in the United States include an initial clean-up of the previous concrete before hardening, by means of air and water jets. This removes the bulk of the laitance and leaves the aggregate itself exposed. Unless, however, the time between the placing of lifts is short, such a surface is liable to become contaminated, and American practice appears to be tending towards the general use of wet sand blasting for the final clean-up.

In Britain, scabbling of the hardened concrete, either by hand or by compressed-air equipment, has been more common. Whichever clean-up method is used, it is essential that the concrete be washed thoroughly, preferably with water, air, or air-water jets, and all rubbish removed, just before the new concrete is placed. Placing should be preceded by working a layer of mortar, of about the same consistency and cement content as the mortar portion of the main concrete mix, into corners and depressions in the old surface.

Whenever concrete is exposed to view, construction joints should only be made at pre-arranged positions, whether they are horizontal or vertical, since it is impossible to mask them, and they should become a feature of the final appearance.

Handling and Placing

The method of handling must be such that segregation or loss of cement mortar or grout from the concrete is avoided. The time interval between mixing and placing is not of serious importance, providing the loss in workability which occurs, owing both to the stiffening of the cement paste as the chemical reaction commences, and to the evaporation of moisture from any exposed surface, does not make placing difficult. With these provisions it has been shown that no serious loss in strength occurs in temperate climates, even if the placing is delayed for 2 or 3 hours. In tropical countries, these factors become more serious and placing should be completed as quickly as possible, shade being provided so far as practicable. The strength of concrete placed at 100° F. may be 20 per cent lower than that placed at 40° F.

Bottom-dump buckets provide a satisfactory means of handling concrete under many conditions, but they must be provided with wide opening doors if trouble in dumping stiff concrete is to be avoided.

If lorries are used for transport, the effect of vibration in the lorries is more apparent in wet lean mixes than in richer and drier mixes.

The pumping of concrete is a satisfactory means of transportation on many sites and, provided the mix is uniform and of suitable consistency, no particular trouble should be experienced. Pumping is most suitable for mixes richer than, say, about 1 : 7 (cement : total aggregate). Leaner mixes can be pumped if suitable aggregate is available, and reliance can be placed on good control of the concrete mix. Concrete pumps are subject to considerable wear, and it is possible for the water intended to clean up the pistons to leak past the gland into the concrete. Close observation should be maintained at the end of the pump line for any signs of increased water content compared with that of the mix entering the pump. In hot countries the pipeline should be buried or otherwise protected from the heat of the sun.

The absence of honeycombing, stone pockets, and other similar troubles, depends to a considerable extent on the skill used in placing the concrete. The concrete should not be allowed to fall from a height without the use of some form of trunking or baffle, in order to prevent separation by hitting reinforcement and other obstructions. It should be placed at a uniform level, flow from one end of the shuttering to the other being avoided, and it should be carefully spaded into corners and round congested reinforcement (see *Fig. 4*). Controversy often arises on the question of the height of pour which should be allowed, particularly in columns,

but this is of far less importance, from the point of view of the elimination of concreting troubles, than the necessity for careful workmanship. Some of the best concrete the Author has seen, including numerous columns 10 feet or more in height, poured in one lift together with the usual main and secondary beams, and without any evidence of such blemishes as segregation and stone pockets, was produced by a building foreman who was prepared to take a little extra care in placing and consolidation. The small extra cost involved was more than offset by the elimination of the need for filling or patching.

Consolidation

The importance of proper consolidation has been demonstrated by the Road Research Laboratory,[4] who have shown the marked decrease in strength resulting from the presence of even small percentages of air voids. These air voids result both from the evaporation of water in excess of that required for hydration of the cement, and from air bubbles left in the concrete after consolidation. The lower the quantity of water used in mixing, the less workable the concrete becomes, and the greater is the effort necessary to eliminate the air bubbles.

It follows that the water/cement ratio and workability of the mix must be closely linked with the method of consolidation to be adopted, and it is, in fact, necessary when using mechanical methods of consolidation to adjust the workability to suit the particular equipment being used. The reduction in water/cement ratio possible when vibratory methods of consolidation are adopted gives an increased strength, or alternatively, enables a leaner mix to be used. It should be remembered, however, that a lean dry mix is more difficult to produce and transport, segregates more readily, and requires more careful placing than a richer and more plastic mix. This and the cost of vibrators often largely offsets the saving in cement.

Vibratory methods of placing facilitate the use of drier mixes, but a number of precautions are necessary to obtain satisfactory results in the field. These are :—

(1) The use of heavier formwork and careful fixing of all parts likely to be shaken loose by vibration.

(2) Insertion of poker vibrators, when used, at frequent intervals, say, 18- to 30-inch centres, and as nearly as possible in a vertical direction only. They should be slowly inserted and withdrawn, 5–15 seconds being sufficient, and they should not be inserted nearer than about 4 inches from the formwork.

(3) Internal vibrators should never be used to move concrete along the forms. This practice results in segregation and allied troubles.

(4) A certain amount of spading or slicing should be carried out between any reinforcement and the formwork, in order to

release air bubbles which are apt to be trapped against the forms when vibrators are used.

Blanks[6] suggests that far more damage has been done and poorer results obtained through under-vibration than from over-vibration, and suggests that if laitance rises to the surface the slump should be reduced and not the vibration. He further suggests that there is no harm in re-vibration when it is performed as late as the concrete will again become plastic, and it may even be beneficial.

There is much to be learned about concrete vibrators, especially the relative efficiency of internal and external vibrators, and on the effect of period of vibration, and of amplitude and frequency. Present evidence indicates that vibrators working at speeds of 6,000 or more revolutions per minute provide better consolidation than those of lower frequency for structural concrete, although a much lower frequency is probably beneficial for roadwork.

Curing and Finishing

Considerable ingenuity may be required in arranging an economical method of curing for different parts of a concrete structure. The object should be to minimize evaporation of the water already existing in the concrete by protective coverings and to replace evaporation losses by wetting. It is very doubtful whether membranes produced by spraying liquids on to concrete provide an effective protection. In hot weather, wetting also helps to keep the concrete cool and so reduce temperature changes, and consequent shrinkage movements.

Concrete may be finished in a number of ways, but the prerequisite in each case is the provision of good sound concrete. Without this none of the finishes available will give satisfactory results.

Patching is never satisfactory unless an area of the surface to a depth of 2–3 inches is cut away to an extent which will enable the joints round the patch to fall in with the general finished pattern of the surface. It may then be necessary to shutter-up the area to be patched, and to cast on a new face.

Concrete Test Cubes

Concrete test cubes are generally regarded as the chief measure of control of concrete quality, but since the tests can only be made on a very small amount of concrete taken from a very small proportion of the various batches produced during the course of the work, they can only serve as a general guide. Further, they should be regarded only as a measure of the quality of the concrete as produced at the mixer, since lack of consolidation or inadequate curing may substantially reduce the strength of the concrete in the structure compared with that of the cubes. Efforts are being made

to provide a more satisfactory means of testing concrete, and perhaps the most promising is the ultrasonic method,[14] by which the concrete in the structure is tested directly. Further research will be necessary, however, before the method can be accepted for general use.

The variability in concrete strength has been well established, and due allowance must be made for this in any control measures. It is usual to specify a minimum cube strength and, since the variability depends on the method of production and the control adopted on the site, the average strength necessary must be assessed from a knowledge of these circumstances.

Sparkes[15] gave some evidence in 1945 of the extent of the variations on a number of sites and has since shown[16] how these variations arise. Further data on the variations in concrete cube strengths are summarized together with comparable previously published data in Tables 2 to 7 (see Appendix). Tables 4 and 6 include results made available by other authorities for the purpose of this Paper. For definitions of standard deviation, coefficient of variation, and total variation, reference should be made to B.S. 600R : 1942.

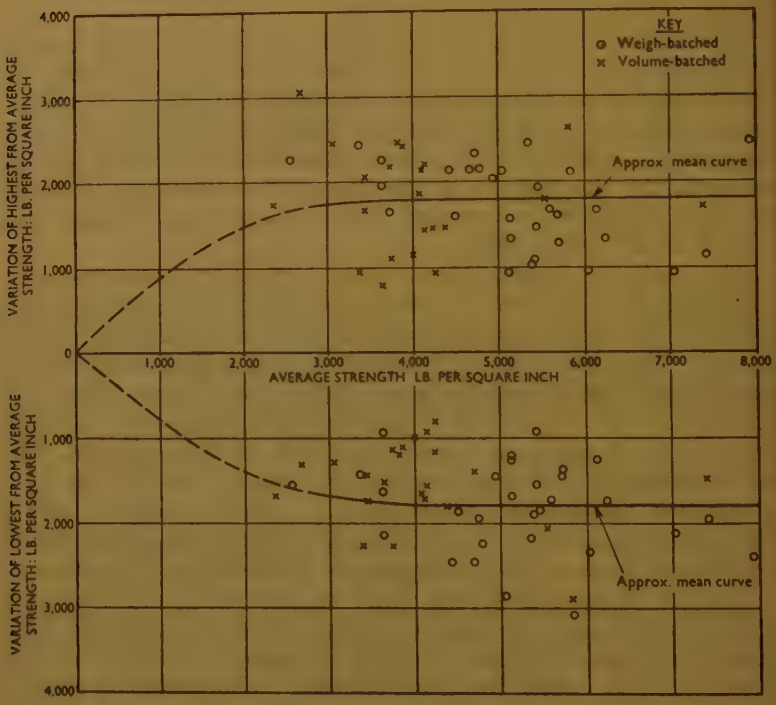
The results for London Airport given in Table 2 are particularly interesting since a large number of cubes were made from concrete of uniform workability and with very little variation in the aggregate over a number of years. There have been small annual changes in the average strength, and the coefficient of variation is seen to have been reduced from about 9 per cent for the period 1945–47 to 6 per cent in 1950, which is believed to be the lowest figure ever recorded for such extensive concrete works, and is attributed to the control measures adopted on the site and to co-operation between the contractor, the resident engineer, and the cement manufacturer. It should be noted in this connexion that the bulk of the cement used on London Airport was obtained from one source only.

Analyses of cubes from sites where weigh-batching was adopted are given in Tables 3 and 4, the former including only those sites where quality control was known to be good. In Table 4 there may be included a number of sites on which control was good, although no information is available to confirm this. In general, it appears that the total variations from the highest to the lowest cube should not exceed about 50 per cent of the average strength with good control, except on some types of reinforced concrete where the need for changes in workability has necessitated variations in the water/cement ratio. Without good control much larger variations can occur, even with weigh-batching, as seen in Table 4.

The variation in cube strength which occurs with volume-batching depends to a much greater extent on the equipment used and the control measures adopted, as will be seen in Tables 5 and 6. Whilst the results obtained on some sites are as good as those obtained on many sites with weigh-batching, on others the results indicate a very large variation indeed, indicating poor control over the proportioning of the materials.

Three possible measures of the effectiveness of quality control are quoted in the Tables, namely, the total variation, the standard deviation, and the coefficient of variation. It is interesting to consider how these vary with the general quality of the concrete, and for this purpose the variation from the average and the standard deviation calculated for each site are plotted against the average strength in *Figs 10* and *11*. Considerable scatter in the results is evident in both cases, but it is clear that for average

Fig. 10



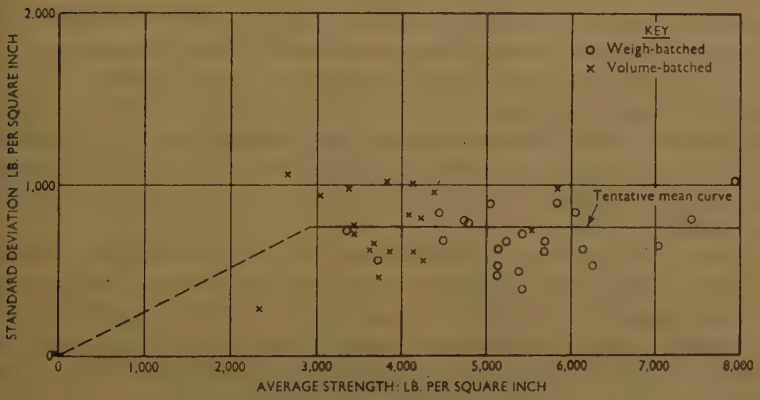
MAXIMUM AND MINIMUM RECORDED STRENGTHS PLOTTED AGAINST AVERAGE STRENGTH FOR EACH SITE

strengths of more than about 3,000 lb. per square inch, neither the total variation nor the standard deviation shows any indication of increasing with increasing strength. A tentative mean curve has been drawn horizontally at a variation of $\pm$ 1,800 lb. per square inch in *Fig. 10*, and at a standard deviation of 750 lb. per square inch in *Fig. 11*. In both cases the curve must pass through the origin, and tentative dotted extensions are indicated. In the absence of better information it is suggested that the variation in cube strength is assumed to be proportional to the average strength up to 3,000 lb. per square inch, and constant above this figure.

The efficiencies of weigh-batching and volume-batching have been compared by determining the overall distribution of cube strengths as shown in Table 7. The results used in making the determination are stated at the head of each column. In considering the results given in Table 6, Site No. 36 was omitted, since the detailed information was not available, and Sites Nos 49, 50, and 51 were omitted because they applied to continuous mixers in which the method of proportioning was quite different from that normally adopted for volume-batching. No analysis is given for the results in Table 5, in view of the small number of sites included.

If it is accepted that 1 per cent of the cube strengths are ignored as resulting from extraneous errors, then there is little difference between

Fig. 11



STANDARD DEVIATION COMPARED WITH AVERAGE STRENGTH

the results in columns (2) and (3), the overall variation being from approximately 2,000 lb. per square inch above the average, to approximately 2,000 lb. per square inch below the average in both cases. This would appear to indicate that with the miscellany of unknown control conditions which are presumed to have existed on the sites included, there is little difference between the results achieved by weigh-batching and by volume-batching. There is, however, a slight difference in the distribution of the results, which is reflected in the difference in the standard deviations. The explanation is thought to be that with weigh-batching the general variation is smaller, but a few wide variations occur when mechanical and other troubles develop in the weighing equipment. With volume-batching there is probably a greater general scatter owing to the lower accuracy of the method, but because of the simplicity of the equipment, the larger sporadic errors are no more frequent than with weigh-batching.

The improvement in the uniformity of the results when good control is allied to weigh-batching is clearly indicated in Table 7. Again ignoring 1 per cent of the results, the overall variation appears to have been from about 1,400 lb. per square inch above to about 1,500 lb. per square inch below the average. Since some sites included in columns (2) and (3) may have been subject to reasonably good or good control, a probability which is reflected in the comparatively low standard deviations at such sites as Nos 13, 16, 20, 42, and 45, it follows that the difference between good control and poor control must be at least as great as that indicated by the difference between columns (1) and (2). Good control may, therefore, be said to decrease the difference between the highest or lowest cube strength and the average by at least 500 lb. per square inch, that is, a reduction in the total variation of more than 1,000 lb. per square inch.

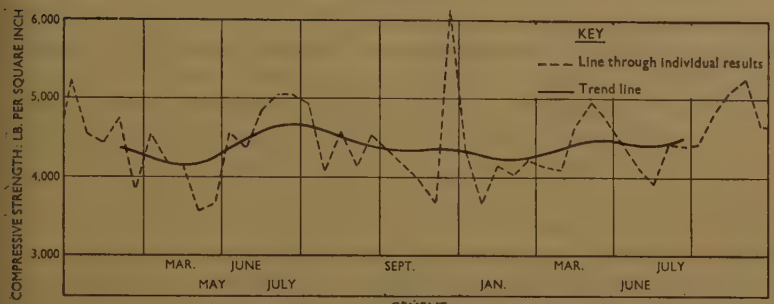
It is, perhaps, unfortunate that it has not been possible to obtain more information on cube strength on sites where good control has been allied to volume-batching with deep containers forming part of a central mixing plant with overhead storage hoppers, so that a direct comparison could be made with sites using weigh-batching and good control. For the moment it appears that good control is the more important factor, although this probably arises because weigh-batching machines are not satisfactory unless they are properly maintained and are accurately checked at regular intervals, a condition which is only achieved on sites where the control is also good.

It is obvious that much further research is required on this point, and the greater the amount of information made available for analyses such as those given in the Tables, the more valuable will the results become.

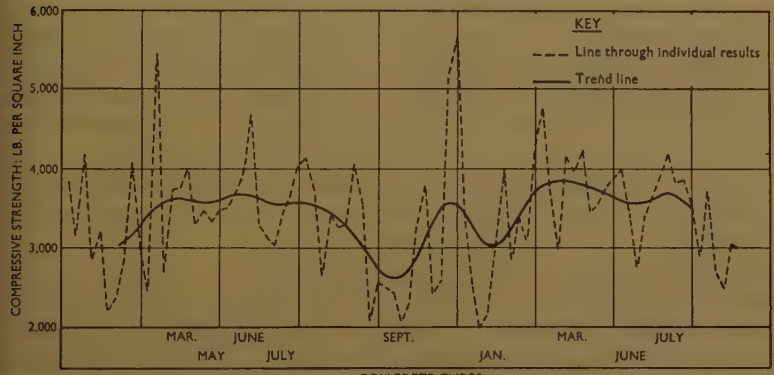
Another method of analysis is illustrated in *Figs 12*, which is a diagram based on time-series analyses of concrete cube strengths and cement strengths, taking a moving average of five results, repeated three times, after which the variation of the cube results about the moving average or trend line was found to be purely random. Plotted to the same time scale is the water/cement ratio recorded on the site, the changes with the time having been necessitated by changes in the grading of the sand, differences in placing conditions, and other factors. Some similarity may be seen between the trend lines for concrete cube strengths and water/cement ratios, and the high cement strengths recorded about the middle of the period of observation were certainly accompanied by high concrete cube strengths, but other factors such as the density of the cubes are obviously influencing the results.

On most sites, changes in the grading of the sand, differences in workability required for differences in placing conditions, and other factors make some changes in the water/cement ratio necessary from time to time, and these are not normally recorded with sufficient accuracy for them to be taken into account in any statistical analysis of the cube strengths. The number of cubes made is also too small on most sites to be of much

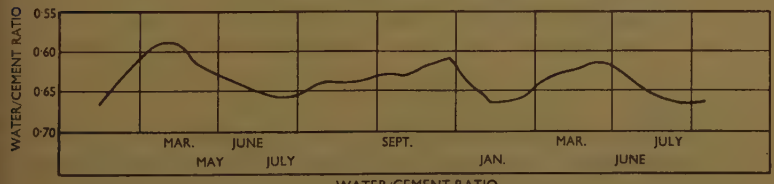
Figs 12



CEMENT
28-day mortar cube strengths taken in chronological order
Horizontal scale is roughly but not exactly a time scale



CONCRETE CUBES
3-month cube strengths taken in chronological order
Horizontal scale is roughly but not exactly a time scale



WATER/CEMENT RATIO

Analysis of Concrete Cube Strengths and Cement Strengths and Comparison with Water/Cement Ratio for Site 22/2

For the period shown in this diagram, the total variation in cube results = 3,660 lb. per square inch. Total variation determined from oscillation of actual results about the trend line = 3,250 lb. per square inch.

use statistically. With such variants unaccounted for, the standard deviation would be expected to be least on works requiring large quantities of concrete of uniform workability, such as road or airfield pavings, and this is borne out in practice. Even then, an upward or downward trend in the concrete strengths over a period, whilst increasing the standard deviation or coefficient of variation, may be caused by a similar trend in cement strengths, and not to a weakening of quality control.

Although these limitations on the value of statistical analyses must not be overlooked, such analyses, if carefully interpreted, are useful as an indication of the variations in cube strengths which might be deemed reasonable under a variety of site conditions. This knowledge is of importance both in mix design and in day-to-day control on the site. Variations in strength which must be expected in site concrete have been assessed from the information quoted in Tables 2 to 6 and are given in Table 8 (see Appendix). In presenting this Table, the Author realizes that much further information is required to confirm the variations in strength given here for guidance.

In designing concrete mixes it may be desirable to allow for slightly more variation than that given in Table 8, unless the designer is prepared to accept a small proportion of the cube results, say, 2–3 per cent, falling below the specified minimum strength. The proportion of cube-strength failures to be allowed depends on the importance of the structure itself, and for some purposes, such as mass-concrete foundations where the soil is not likely to contain deleterious salts, might even be increased beyond 2–3 per cent.

One aspect of the variations quoted in Table 8 which should be noted is the lower average strength possible whilst still giving the required minimum strength, when good control and weigh-batching are adopted. This lower average can be achieved with a leaner mix, thus showing a saving in cement which is often quite substantial. It is unfortunate that in so many specifications the contractor is not given an opportunity to effect such savings by careful mix design and control on the site.

Conclusions

The control of concrete quality calls for a co-operative effort on the part of the contractor, the design engineer, and the technologist, to ensure that not only are the right materials and techniques employed, but that a multitude of details are correctly carried out. In this the concrete technologist should use every approach possible to achieve good results, including educational measures aimed at all grades of site personnel.

Concrete technology is largely neglected in the universities and technical colleges, and it is desirable that some of the emphasis on design should be lessened in favour of practical training in the production of concrete, thus giving the student a more balanced knowledge of the subject.

Statistical analyses are useful in assessing the variation in concrete cube strength to be expected under various site conditions, but are of direct value only to the site engineer on the largest jobs.

Quality control embraces the whole field of concrete technology and it has been possible to give only a brief outline of many of the items involved, but emphasis has been placed on the importance of correct proportioning of the materials in order to produce a uniform cohesive concrete of suitable workability for the particular conditions of placing and consolidation.

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The Paper is accompanied by nine photographs and four sheets of drawings, from some of which the half-tone page plates and the Figures in the text have been prepared, and by the following Appendix.

APPENDIX

TABLE 1.—VARIATION IN CRUSHING STRENGTH OF VIBRATED MORTAR CUBES MADE WITH CEMENT FROM VARIOUS SOURCES

Source or site	Number of samples tested	Age at time of test : days	Average compressive strength of cubes : lb. per sq. in.	Variation from highest to lowest strength : per cent of average strength	Standard deviation	Coefficient of variation
Source 1	41	3	2,730	86	710	26
	41	7	3,820	60	610	16
Source 2	17	7	4,350	21	—	—
Source 3	19	7	4,190	41	—	—
Source 4	18	7	3,650	60	—	—
Source 5	147	28	4,410	61	510	11·6
London Airport [7]	61	7	4,250	45	424	10·0
	66	28	6,313	41	572	8·9
Site A [2]	59	7	3,970	65	—	—

Notes.—(1) Samples taken at random.

(2) All vibrated mortar cubes made and cured under similar conditions with temperature 64° ± 1° F.

(3) Variations are based on mean strength obtained from three cubes tested at each age from each sample of cement.

(4) At Site A, cement was taken from more than one source.

(5) All samples were of ordinary Portland cement, B.S. 12 : 1947, except Source 5, which was low-heat cement, B.S. 1370 : 1947.

TABLE 2.—ANALYSIS OF CUBE STRENGTHS OBTAINED ON CONCRETE FROM LONDON AIRPORT

Year	Month	Number of cubes tested at 28 days	Average compressive strength at 28 days : lb. per sq. inch	Standard deviation	Coefficient of variation
1945	all	5,189	5,840	527	9·0
1946	all	4,704	5,640	487	8·6
1947	all	4,350	5,690	517	9·1
1948	all	5,964	6,120	494	8·1
1949	all	4,400	6,180	491	8·0
1950	Jan.	—	6,430	489	7·6
	Feb.	—	6,720	470	7·0
	Mar.	—	6,720	370	5·5
	Apr.	—	6,940	174	2·5
	May	—	6,570	322	4·9
	June	—	6,140	479	7·8
	July	—	6,510	334	5·1
	Aug.	—	6,900	339	4·9
	Sept.	—	6,140	408	6·65
	Oct.	—	6,490	322	5·0
	Nov.	—	5,920	483	8·2
	Dec.	—	5,740	365	6·4
	All	4,115	6,435	384	6·0

Notes.—(1) The standard deviation in this and the ensuing Tables has been calculated on cubes taken individually.

(2) Mix 1 : 6·1 by weight (cement : total aggregate), 1½ inch nominal max. size.

(3) Water/cement ratio 0·47 to 0·49.

(4) Approx. one cube tested for every 30 cubic yards of concrete.

(5) Output of concrete in 1950 ranged from 3,539 to 15,417 cubic yards per month.

(6) Cement was tested in 1945 and 1946 only in sufficient quantity to make comparison possible. Summary of results :

Year	Average vibrated mortar cube strength at 7 days (B.S. 12 : 1947) : lb. per sq. inch	Coefficient of variation
1945 . .	4,240	9·3
1946 . .	3,600	12·6

See also Table 6 for other results

TABLE 3.—ANALYSIS OF CUBE STRENGTHS FOR SITES WHERE WEIGH-BATCHING WAS IN USE, AND MAINTENANCE AND CONTROL WERE KNOWN TO BE GOOD

Site No.	Mix proportions: parts of total aggregate to 1 part cement by weight	Approximate water/cement ratio	Number of cubes tested	Compressive strength at 28 days: lb. per sq. inch				Standard deviation	Coefficient of variation
				Highest cube	Lowest cube	Total variation: per cent of mean	Average		
1	7·5	0·52	172	6,720	3,860	56	5,130	526	10·2
2	4·9	—	128	6,980	4,250 *(1,180)	48	5,700	674	11·8
3	5·3	—	182	7,580	4,520	49	6,260	526	8·4
4	5·25	—	163	7,300	3,920	59	5,690	604	10·6
5	5·4	—	38	7,020	3,710	55	6,040	841	13·9
6	4·9	—	115	6,430	3,490	55	5,390	498	9·3
7	5·1	—	40	6,470	4,470	37	5,410	398	7·4
8†	6·0	—	36	5,400	2,800	70	3,740	552	14·8

* Odd low cube-result.

† Small reinforced-concrete structure using 10-cubic-foot mixer and small weigh-batcher. See also Table 2 (Heathrow results).

Site No.	Mix proportions: parts of total aggregate to 1 part cement by weight	Approximate water/cement ratio (as claimed)	Number of cubes tested	Compressive strength at 28 days: lb. per sq. inch				Standard deviation	Coefficient of variation
				Highest cube	Lowest cube	Total variation: per cent of mean	Average		
9	5·2	0·45	44	8,530	5,440	42	7,410	800	10·8
10	5·5	—	216	7,050	2,760	91	4,730	797	16·8
11	4·9	—	136	6,100	2,630	75	4,500	670	14·9
12	5·5	—	264	6,560	1,970	103	4,430	838	18·9
13	5·3	—	28	6,050	3,900	42	5,120	492	9·6
14	5·2	—	167	7,150	2,170	99	5,040	890	17·6
15	5·1	—	78	6,920	3,900	55	5,440	705	13·0
16	5·3	—	32	6,470	3,460	58	5,150	624	12·1
17	5·3	—	189	7,940	2,750	89	5,840	899	15·4
18	5·5	—	130	6,940	2,570	91	4,790	782	16·3
19	5·4	—	50	7,990	4,930	43	7,040	646	9·2
20	5·3	—	77	7,810	4,870	48	6,140	622	10·2
21	(American dam) [4]	—	—	—	—	—	5,210†	657	12·6
*22/1	3·9	—	96	10,450	5,570	61	7,790	1,025	12·9
‡22/2	(approx.) 9·8	0·60–0·65	256	‡5,790	‡1,930	114	3,370‡	747	22·2
23	1 : 1 : 2	—	54	7,600	4,000	60	5,630	—	—
24	1 : 1 : 2	0·55	95	7,000	3,500	69	4,965	—	—
25	1 : 1½ : 3	—	64	4,800	1,000	150	2,550	—	—
26	1 : 1½ : 3	—	169	5,900	1,500	119	3,640	—	—
27	1 : 2 : 4	—	505	6,800	2,220	98	4,680†	—	—
28	1 : 6	0·45	72	7,400	3,600	70	5,465	—	—
29	1 : 6	0·43	48	7,280	3,880	61	5,595	—	—
30	1 : 6·05	—	986	7,800	3,160	87	5,350†	—	—

* Concrete used in prestressed units.
† Cube strength assumed 4/3 times 12-inch × 6-inch cylinder strength.
‡ Low-heat cement. Cubes tested at 3 months.
Sites Nos 23–30 quoted by Sparkes [14] in 1945.

TABLE 5.—ANALYSIS OF CUBE STRENGTHS FOR SITES WHERE VOLUME-BATCHING OF AGGREGATES WAS IN USE, SPECIAL ARRANGEMENTS BEING MADE IN THE CONCRETE PLANT SET-UP FOR BATCHING, OR SPECIAL EFFORTS BEING MADE TO MAINTAIN GOOD CONTROL

Site No.	Mix proportions as stated by volume	Number of cubes tested	Compressive strength at 28 days : lb. per sq. inch (unless otherwise stated †)				Standard deviation	Coefficient of variation
			Highest cube	Lowest cube	Total variation : per cent of mean	Average		
31*	1 : 2½ : 5	18	5,200	3,450	41	4,260	560	13·2
32*	1 : 2 : 4	32	4,420	2,120	63	3,640 [7]	623	17·1
33/1	1: :1¼ : 2½	148				4,020 [7]	471	11·7
33/2	1 : 1½ : 3	207				3,170 [7]	556	17·5
34	1 : 1½ : 3	127				2,790 [7]	481	17·2

* Works on which the concrete was produced by 10-cubic-foot mixers.
† Results at 7 days have been quoted in the absence of information on these sites on 28-day strengths.

TABLE 6.—ANALYSIS OF CUBE STRENGTHS FOR SITES WHERE VOLUME-BATCHING OF AGGREGATES WAS IN USE, AND EITHER THERE WAS NO SPECIAL BATCHING EQUIPMENT OR NO INFORMATION IS AVAILABLE ON THE METHOD USED

Site No.	Mix proportions as stated by volume	Number of cubes tested	Compressive strength at 28 days: lb. per sq. inch				Standard deviation	Coefficient of variation
			Highest cube	Lowest cube	Total variation: per cent of mean	Average		
35	1 : 2⅛ : 5	29	5,940	2,410	86	4,080	836	20·5
36	—	270	—	—	—	3,670	640	17·4
37	1½ : 2½ : 5	21	5,730	1,370	163	2,680	1,068	39·9
38	1 : 2 : 4	22	5,480	1,740	123	3,030	940	31·0
39	1 : 2 : 4	20	5,670	3,040	62	4,210	803	19·1
40	1 : 2 : 4¼	169	8,420	2,910	95	5,810	987	17·0
41	1 : 1⅜ : 3⅜	133	7,330	3,460	70	5,530	740	13·4
42	1 : 2¼ : 4⅛	60	5,550	3,140	59	4,110	619	15·1
43	1 : 2 : 4	26	6,250	2,610	96	3,810	1,023	26·9
44	1 : 1½ : 3	20	5,850	2,580	74	4,390	964	22·0
45	1 : 2 : 3½	60	6,280	2,740	92	3,860	615	15·9
46*	1 : 2½ : 5	48	4,090	750	142	2,345	827	35·3
47	1 : 1¾ : 3¾	49	6,290	2,550	91	4,110	1,019	24·9
48	1 : 2 : 4	28	4,350	1,110	96	3,390	989	29·2
49	1 : 2 : 4†	147	5,090	1,960	92	3,420	729	21·3
50	1 : 2 : 4†	102	4,920	2,610	62	3,730	471	12·6
51	1 : 2 : 4†	140	5,470	1,650	112	3,410	765	22·4
52	1 : 2 : 4	718	5,150	3,000	53	4,000‡	—	—
53	1 : 2 : 4	900	5,900	1,450	119	3,720‡	—	—
54	1 : 2 : 4	150	6,240	2,400	94	4,100‡	—	—
55	1 : 1 : 2	23	8,700	5,900	38	7,400	—	—
56	1 : 2 : 4	28	6,800	3,300	74	4,700	—	—

* Site control stated to have been poor.
† Continuous mixer.
‡ Cube strength assumed 4/3 times 12-inch × 6-inch cylinder strength.
Sites Nos 52–54 quoted by Sparkes [14] in 1945.
Sites Nos 55, 56 given in Building Research Board Annual Report, 1933, p. 79.

TABLE 7.—COMPARISON OF OVERALL DISTRIBUTION OF CUBE STRENGTHS

Variation above or below average strength: lb. per square inch	Percentage of total number of cubes within each range indicated		
	Table 3 (Sites 1 to 8)	Table 4 (Sites 9 to 20, 22/1, and 22/2)	Table 6 (Sites 35, and 37 to 48)
	Weigh-batching, good control	Weigh-batching, control unknown	Volume-batching, control unknown
	(1)	(2)	(3)
Above:			
3,200—2,800	—	—	*
2,800—2,400	—	*	*
2,400—2,000	—	1	1
2,000—1,600	*	2	2
1,600—1,200	2	4	6
1,200— 800	6	9	7
800— 400	18	15	12
400— 0	27	20	19
Below:			
0— 400	24	21	19
400— 800	16	13	13
800—1,200	5	9	12
1,200—1,600	1	4	6
1,600—2,000	(0·5)	1	2
2,000—2,400	*	1	1
2,400—2,800	—	*	*
2,800—3,200	—	—	*
Averages of standard deviations: lb. per sq. in.	580	750	850
Approximate average compressive strength: lb. per sq. in.	5,400	5,500	3,900

* Less than 0·5 per cent.

TABLE 8.—SUGGESTED LIMITING CUBE STRENGTHS FOR USE IN QUALITY CONTROL

Method of proportioning, type of concrete, and control measures	Variations above or below average strength beyond which investigation is advisable	
	For average strengths below 3,000 lb. per sq. in.: percentage variation from average	For average strengths above 3,000 lb. per sq. in.: difference from average in lb. per sq. in.
All materials by weight. High quality concrete of uniform workability in large quantities.	33	1,000
All materials by weight. High quality concrete in members of varying sections requiring slight changes in workability.	40	1,200
All materials by weight. General concreting where constant supervision is not justified. Lean mixes.	50	1,500
Aggregates by volume using deep bins for measurement. Cement by full bag or by weight. Good control.	40	1,200
Aggregates by volume. Cement by full bag or by weight. Measurement of aggregates by marks in loading hopper or by gauge boxes, without constant supervision.	50	1,500
Aggregates by volume. Cement by bag or part bag. Little control.	60	1,800
*All materials by volume	70—80	2,100—2,400

Note.—Total variation is twice the value quoted.

* Cement should never be measured other than by weight. The figures are given to indicate the extent of the variation which results if weight measurement is not adopted.

Paper No. 5916

"Repairs to Sea-Outfall Sewer on the Storm-Beach in Chesil Cove, Dorset"

by

Harold Dempster Rimmer, B.Eng., A.M.I.C.E.

(*Ordered by the Council to be published in abstract form*) †

Site

Chesil Cove is the point at which the eastern end of the Chesil Bank meets the high rocks of Portland Bill. It is open to the Atlantic on the south-west, the direction of the prevailing wind, and a very light breeze from that sector renders boat work impossible, whilst even moderate winds raise very high seas.

Any westward shift of wind through south is critical and unpredictable, and the weather is thus extremely treacherous. A vessel caught in the cove by bad weather is land-locked off the lee shore, with its nearest refuge 15 miles to windward in West Bay, or alternatively in Portland Harbour, to reach which it is necessary to beat round Portland Bill and pass through, or avoid, Portland Race.

The beach is composed entirely of flinty pebbles, and great changes in cross-section occur with varying weather. Even in the calmest weather each tide will see a number of miniature storm-beaches built up and pulled down, and the grinding of the shingle near low water is so severe as to cut through 1 inch of cast iron in 2 years.

The existing sewer was cast iron, 12 inches internal diameter and 1 inch thick, supported on single cast-iron piles. About 150 feet of sewer pipe below low-water mark had disappeared, and the Engineers prepared a scheme for its replacement by a manganese-steel pipe of similar dimensions, carried between armour-plate saddles and transomes, which were to be secured by stainless-steel U-bolts to 4-inch-diameter solid manganese-steel piles. Since access for maintenance would be difficult, considerable redundancy was provided in the fastenings.

The pipe and fixings could not be obtained without delays. Therefore, after the driving of the permanent piles, a temporary mild-steel pipe, $\frac{3}{8}$ inch thick, was set upon greenheart saddles and transomes, the permanent pipe, saddles, and transomes being fixed at a later date.

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† The full MS. and illustrations may be seen in the Institution Library.—Sec. I.C.E.

Method of Attack

It was anticipated that during the working season 1 day in 3 could be worked, but owing to an unusual period of easterly winds in August nearly 1 day in 2 was worked. Subsequent analysis of records, however, justifies 1 in 3 as the most probable ratio.

The use of normal floating piling-plant was out of the question, since even if it could be brought into the cove in fine weather, warning of a change of weather would often come so suddenly as to trap it there.

A moderate gale, such as could be expected many times during the working season, would raise sufficient sea to destroy any normal type of gantry of a cost in proportion to the size and importance of the work.

It was suggested that the original work had been carried out from a cage of steelwork, raised and moved on the tide by pontoons, which were moored safely in deep water when not in use. This scheme had many obvious advantages, in particular that of offering a very small amount of plant to the sea at any time, and it was decided to use a crib of tubular scaffolding, driving by hand with a 1-ton monkey.

The first crib was made as a 16-foot cube, divided into eight cells and provided with liberally redundant cross-bracing. Runners of light steel troughing were provided for launching, after which it was intended to move the crib with pontoons. It was erected above high-water mark and dragged down by an outhaul, but owing to difficulties with the pontoons it had to be withdrawn several times, and its movements were impeded by the beach making up and burying it faster than it could be moved. It was finally floated off and deposited correctly 2 feet inshore of the site of the seaward bent of piles. In order to give a longer working period an extra level of scaffolding was then erected, about 4 feet high.

False leaders were floated out on pontoons and dropped on the bottom, and their head was then lifted by a cathead erected on the crib. The foot of the leaders was set in its correct position by diver and they were plumbed from above water level and secured at any convenient points to the crib. The temporary connecting tubes were coupled to tubes welded for the purpose to the leaders.

Raking tubes were then coupled to the ends of the head-sheave shaft, which were carried beyond the leaders for the purpose, and to stubs welded to the winch frame near the axis of the drum. These rakers contained the pull of the lifting wire and rendered ballast unnecessary. The weight of the monkey was carried entirely by the foot of the leaders resting on the bottom. The winch forces being contained as described, the crib had only to provide steadying and a working platform.

The monkey was dropped on the bottom while slewing and re-setting the leaders for the second pile in the bent.

Boats

All access was by boats, which had to be hauled up the beach every night even in the calmest weather. Those used were the " Jessie "—an 18-foot diving boat, and a light 18-foot dinghy. The " Jessie " was hauled up by the shore winch with the diving pump and hoses on board. Boat hauling was extremely arduous for all hands.

Cantilevering Leaders

After driving the first bent the monkey was dropped on the bottom, and the leaders released to allow them to trail from the cathead while the crib was drawn inshore to its second position. While the leaders were suspended from the cathead, and before shifting the crib, the wind shifted to the dangerous quarter so suddenly that there was only time to put a hemp lashing around the leaders before abandoning the work. For 7 days it was impossible to launch a boat. The crib was driven inshore about 6 feet, and turned about 10 degrees through a vertical axis.

During this storm it was decided that two more bents of piles, seawards of the bent already driven, would be required to ensure connexion to an undamaged joint of the existing pipe. The ground was boulder strewn, and to move the crib across it and over the driven bent would have been extremely awkward. The crib was therefore drawn seawards until the centre cross-frame was tight up to the driven bent, the bottom member of the seaward cross-frame being removed temporarily to permit this. The leaders were then cantilevered out from the crib to a maximum outreach of 17 feet (*Fig. 1*).

With the head of the leaders suspended from the cathead, the foot was pulled seawards by the outhaul and bottomed near the site of one of the outermost piles. The head of the leaders was then pushed out from the crib, struts from the outermost top corners of the crib going with it to steady it sideways. As the outreach increased, however, the angle in plan of these struts became " bad," so that it was impossible to maintain lateral control by them whilst erecting. A rather disturbing position was reached finally, in which the leaders were nearly plumb fore and aft, but canted sideways about 25 degrees. The struts were unable to correct this, and in the absence of any means of obtaining a purchase to right the cant, the strut couplings were locked to prevent collapse. A single tube was then set upright alongside the leaders, and its top was braced securely off the crib. This provided a fixed point from which the head of the leaders could be controlled laterally.

Stripping First Crib

After the crib had been hauled into position for the work it was unfit for further useful movement. When the two extra bents had been driven

Fig. 1

LEADERS CANTILEVERED OUT FROM FIRST CRIB

Fig. 2

SECOND CRIB COMING ASHORE

Fig. 3

NORMAL DRIVING WITH SECOND CRIB

the monkey and leaders were dropped, and the crib was stripped down to low-water level. Only the " Jessie " was heavy enough to take substantial loads of scaffolding, and the stripping was done on a day when frequent beaching with a cumbersome load was undesirable. After loading, therefore, she was run inshore, and held just clear of the breakers by a head-rope from the remains of the crib, whilst the load was dragged ashore piecemeal on a rope. This method was as quick as beaching in a flat calm.

The lightened remains of the crib were drawn ashore and dismantled. The bottom was in very bad condition, with several badly bent tubes.

Second Crib

The second crib (*Figs 2* and *3*) was designed for sliding only, and was erected entirely upon a braced tray of 9-inch-by-3-inch timber, to which the hauling bridles were attached. All hauling forces (except winding) were contained by this tray, and the crib itself had only to deal with working loads. In the event, the whole piece of equipment came ashore undamaged at the end of the driving. A more elaborate cathead was provided, to increase the drift when slinging the leaders. This cathead was so arranged that it could be tilted inboard as the slope of the bottom tilted the crib increasingly seawards.

General

Tracks were prepared for the cribs by moving boulders by winch and with explosives.

Setting out was done with strained wires under water.

Special precautions were taken to prevent the shingle bombardment from slacking back the locknuts securing the saddles and transomes.

The Engineers for the work were Messrs John Taylor and Sons, to whom the Author is indebted for permission to publish and for assistance in the preparation of this Paper. As the Engineers' representative visiting the site, Mr H. C. Croucher was able to make helpful suggestions. Mr G. Tapping carried out the whole of the diving work.

The Paper is accompanied by ten photographs and six sheets of drawings.

CORRESPONDENCE

on Papers published in Proceedings Part I, November 1952

Paper No. 5859

"The Measurement of Very Slow Movements in Large Structures" †

by

Harold Leslie Cox and Stanley Edwin Mitchell

Correspondence

Mr W. H. Ward remarked that observations of the movements of structures with the precision and duration of those described in the Paper were scarce. The only other observations of a similar nature that he could recall were those by Mohr *et alia* [11] of the abutments of the railway bridge at Klosters, near Davos. That such long-term movements occurred was evident from even cursory examinations of most historical structures. Indeed, the effects of the movements formed an essential part of the character of old buildings.

It was very difficult, particularly when making measurements of the precision described in the Paper, to ensure that the reference point was fixed or moved in a known way. In order to check that the reference points did not move, it was customary to establish, where convenient, a number of points at different depths in the ground and in different horizontal positions remote from areas that were likely to be influenced by recent changes and by the structures under investigation. Relative observations between those points enabled their reliability to be assessed. Unfortunately, the Darwin method of relative measurement was not suitable for use over long distances and that limitation had no doubt prevented the Authors from making a direct check on the possible movements of the reference points.

Mr Ward was not satisfied from the evidence presented in the Paper that long-term movements of the brick reference piers had not influenced the measurements at the Tower and perhaps the Authors would offer their comments on the following suggestions.

† Proc. Instn Civ. Engrs, Part I, vol. 1, p. 682 (Nov. 1952).

[11] References 11 to 14 are given on p. 460.

One might expect from experiences with similar excavations made for piers [12] through the Thames ballast that the clay would swell locally, not settle as the Authors had suggested, and further that their foundations would tend to tilt the reference points towards the adjacent heavier masses of old masonry—for example, the quay wall and the Salt Tower. Those pier movements, if they were neglected, would suggest settlement of the structures, and, because of the positions of the piers relative to the wharf wall and the Salt Tower, movement of the wharf away from the river and movement of the Salt Tower towards the river. Moreover, the pier brickwork might be expected to increase slowly in length for a long time, like the parapets of buildings did, and that effect, if neglected, would tend also to suggest a settlement of the structures.

In order to demonstrate the secular nature of the Tower movements the Authors had eliminated the rhythmic effects from most of their curves and had perhaps tended to divert attention from the possible net effects of rhythmic displacements. Mr Ward suggested that it was desirable to consider the possibility, even in the case of the Tower, that the secular movement might be the result of the net ratchet effect of the rhythmic movements. The ratcheting movement, caused by seasonal thermal and moisture gradients in conjunction with the action of gravity in rocks and soils were believed to be important processes in geological denudation.[13] Such processes might affect the ground, the pier units, and the Tower masonry.

The Authors' suggestions for the cause of the Rochester Bridge movement, namely, seasonal water changes causing volume changes in the ground and leading to a net movement of the abutment, were in accord with the above suggestions. Records[14] of the moisture changes in the clays of south-east England showed that the greatest change (shrinkage followed by swelling), since the bridge records had been kept, had occurred in 1949. The curve in *Fig. 19* showed an exceptional dip at precisely the same time and that was unlikely to be a coincidence. Whether the 1949 movement was caused directly by large moisture changes or indirectly by the removal of a large body force, arising from the unusually low level of the river, was, of course, unknown.

The Authors, in reply, agreed that a method of measurement suitable for use over long distances, and as accurate as the Darwin method, would, if it could be devised, provide a valuable check on the immovability of the reference points. Mr Ward had suggested an interesting explanation of the shape of the displacement-time curves for the quay wall and the Salt Tower near the beginning of the period of observations; it seemed doubtful, however, whether the whole relative movement shown in *Figs 12*, *13*, and *14*—especially the steady movement in *Fig. 12*—could take place wholly in the reference piers.

The occurrence of the exceptional dip in the curve of *Fig. 19* at exactly the time of the greatest moisture change in the clay of south-east England

since the bridge records had been kept was very remarkable, and lent strong support to the view that the ratchet-like action resulting from alternate shrinking and swelling of the soil was largely responsible for the secular movements detected.

References

11. C. Mohr, R. Haefeli, L. Meisser, F. Waltz, and W. Schaad, "*Umbau der Landquartbrücke der Rhätischen Bahn in Klosters*" ("Reconstruction of a Railway Bridge at Klosters"). *Schweiz. Bauztg*, vol. 65 (1947), pp. 5–8, 20–24, 32–37.
12. L. F. Cooling, "Settlement Analysis of Waterloo Bridge." Proc. 2nd Int. Conf. Soil Mech., Rotterdam, 1948, vol. II, p.130,
13. "Application of Geology to Engineering Practice." Geological Soc. Amer., Nov. 1950. *See* K. Terzaghi, "Mechanism of Landslides," pp. 83–123.
14. W. H. Ward, "Soil Movement and Weather." Proc. 3rd Int. Conf. Soil Mech., Zürich, 1953.

Paper No. 5863

"Pressure of Concrete on Formwork" †

by

Stanley Rodin, M.Sc., B.Sc.(Eng.), A.M.I.C.E.

Correspondence

Dr G. G. Meyerhof observed that the Author had provided a useful summary of previous research of concrete pressure on formwork, and his analysis clearly indicated the many factors involved. In connexion with the arching of concrete it should be noted, however, that Terzaghi's original concept of the effect of wall movement on the magnitude and distribution of pressure was derived from considerations of a relatively large ratio of width/height of material x/h.

For smaller ratios of x/h (less than about one-half), such as for greater depths of concrete between shuttering of walls, columns, and other relatively narrow members, the mechanism of arching and pressure on the formwork was likely to be similar to that found in silos of rectangular or square shape in plan, as the case might be.[38] Thus it was shown that the maximum pressure of granular material in a rectangular container (long wall) was :

$$p_m = \frac{\gamma x}{2K \tan \delta}$$

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† Proc. Instn Civ. Engrs, Part I, vol. 1, p. 709 (Nov. 1952).

[38] M. S. Ketchum, "The Design of Walls, Bins and Grain Elevators." McGraw Hill, New York, 1925, p. 307, and other books.

whilst for a square container (column) :

$$p_m = \frac{\gamma x}{4K \tan \delta}$$

where γ denoted unit weight of material,
x " width of section,
K " ratio of horizontal to vertical pressure
and δ " angle of skin friction between material and sheeting.

In order to ascertain whether wet concrete behaved like a granular material, some exploratory shearing tests had been carried out on cement-mortar at the Building Research Station. A 1 : 3 mix (normal Portland cement to standard Leighton Buzzard sand) with 10 per cent by weight of water had been hand-compacted in a standard shear box at a porosity of about 25 per cent. Immediately after filling the box, the material had been sheared at various normal pressures up to 1 ton per square foot on the shear plane, when the wet mortar had indicated a maximum cohesion of about $c = 100$ lb. per square foot and an angle of internal friction $\phi = 42$ degrees ; the residual values had been about $c = 50$ lb. per square foot and $\phi = 32$ degrees, respectively. Similar shearing tests on the sand alone had given $\phi = 38$ degrees at a porosity of 33 per cent, the minimum which could be obtained by hard ramming.

Whilst much further research was required on the problem, those preliminary experiments would indicate that the soil mechanics principles might be useful in dealing with problems of wet concrete. That approach had also been found helpful in understanding the behaviour of hardened concrete and rock.[39, 40]

The Author, in reply, agreed with Dr Meyerhof that for small values of the ratio x/h the mechanism of arching was probably similar to that found in silos. The " silo formula," however, could not be applied directly to concrete since it made no allowance for the rate of pouring, consistency of the mix, and the rate of increase in shearing strength of the mortar. As shown in the Paper, all of those had an important effect on the lateral pressure of the concrete.

Recent experimental work by the Building Research Department in Norway [41] had, in fact, attempted to establish a relation between the lateral pressure of the concrete and the rate of pouring, which also took into account the " silo effect " of the shuttering. As a result of that work the following empirical formula had been obtained :

$$P = \gamma \lambda R t_s k \left(1 - \frac{h}{R t_s}\right)$$

[39] K. Terzaghi " Stress Conditions for the Failure of Saturated Concrete and Rock." Proc. A.S.T.M., vol. 45, p. 777 (1945).

[40] G. G. Meyerhof " The Bearing Capacity of Concrete and Rock." *Mag. Concr. Res.*, vol. 4, No. 12, p. 107 (1953).

[41] R. Schjødt, " *Betongs Sidetrykk Mot Forskalling.*" Building Research Department, Oslo, 1951.

where P denoted lateral pressure

γ ,, unit weight of concrete

λ ,, $\tan^2\left(45 - \frac{\phi}{2}\right)$, where ϕ denoted the angle of internal friction of fresh concrete

R ,, rate of pour

t_s ,, time of set

h ,, height of concrete above point where pressure was calculated

The value of k was given for a range of values of $\left(\frac{h}{Rt_s}\right)$ and $(c \tan \phi_1 \lambda R t_s)$, where

c denoted ratio of circumference of concrete to area

ϕ_1 ,, angle of friction between concrete and forms.

That formula had been checked by a series of measurements on buildings under construction, using electric strain-gauges attached to tie-rods in the concrete formwork. Although a large scattering of results had been obtained, the measured loads had, in all cases, been less that the calculated ones.

A further interesting result of those experiments had been that ϕ_1, appeared to equal ϕ. For the wet concrete, ϕ had been found to be approximately equal to 15 degrees. A similar figure was also given by Ljungberg.[42] That compared with the much higher value of 42 degrees obtained at the Building Research Station for a cement-mortar, which, with a water content of 12 per cent, might be considered to have a relatively dry consistency.

[42] N. Ljungberg, "*Formar och Ställinger, i Betongteknisk Anvisiningar*," Stockholm, 1945.

CORRESPONDENCE

on a Paper published in Proceedings, Part I, May 1953

Paper No. 5912

"The Claerwen Dam"

by

Horace Denton Morgan, M.Sc.(Eng.), M.I.C.E.,
Peter Adamson Scott, B.Sc., M.I.C.E.,
Rupert Joseph Crawhall Walton, M.I.C.E.,
and
Richard Hone Falkiner, B.A., B.A.I., A.M.I.C.E.

Correspondence

Dr O. C. Zienkiewicz suggested that the information referring to concrete control and the use of wetting agents, as well as the experience gained in the use of unusually large aggregates and new methods of fixing shuttering, should greatly advance the design and construction of dams. Temperature records proved the usefulness of low-heat cements, showing a decrease of 30° F. in the maximum temperature as compared with Laggan dam temperature records. A further analysis of the temperature data, considering the effects of time intervals allowed between concreting overlying lifts and adjacent blocks, would have been very instructive.

He felt that the method of gravity dam design suggested in the Appendix to the Paper deserved some comment. The calculation presented was based upon the same assumptions as that of all classical theories of dam design, that was, linear distribution of stress, and although that theory did not hold true near the base of the dam (as had been shown previously[10]), it nevertheless provided a workable assumption for finding the stress distribution in the upper regions of a dam profile. Since the "middle-third" rule was a logical consequence of the very same assumption, he found its criticism in the Paper somewhat puzzling. The fact that, for dams of considerable height, the "middle-third" rule had to be supplemented by requirements limiting the maximum stress to permissible values, did not cast a slur on its validity as a criterion for prevention of tensile stresses. The method of calculation proposed seemed to contain two fallacies.

[10] O. C. Zienkiewicz, "The Stress-Distribution in Gravity Dams." J. Instn Civ. Engrs, vol. 27, p. 244 (Jan. 1947).

First, the equations were valid only when "t" was greater than "u" (see *Fig. 21*). That could only be true when the line of thrust was outside the middle third, that was to say, after tension had in fact developed and "cracked" the section over the length $(t - u)$. Since such a crack would cause full uplift pressure to develop in that length, such a section could not be accepted as satisfactory. It was stated in the Paper (p. 253) that . . . "In the upper levels the profile does not conform with the formula, the widths being greater than those calculated. . . ." A simple check would show that they conformed to the "middle-third" requirement. At greater depths, when the middle third had to be supplemented by the stress requirement, the formula broke down since u became greater than t. The second point of criticism would be that the maximum stress occurred in the principal stress direction, that was, parallel to the downstream face of the dam, and that was, in fact, the stress which logically should be limited to the desired value (it could easily be shown that that stress was equal to $\frac{q}{\sin^2\alpha}$ where α denoted the angle of inclination of the face to the horizontal).

Mr J. C. Gullen referred to the statement on p. 261 that "Considerable variations were evident in the vibrated-mortar cube-strengths (Fig. 12, Plate 1) . . . eight of the sixty-nine samples failed to reach the specified 28-day strength."

He did not agree that that was attributable to the behaviour of the dicalcium silicate component as suggested, but rather to the amount present, which at times had varied owing to the occasional but unavoidable use of high-ash-content coal for cement burning; coal had to be accepted by the cement manufacturers regardless of ash content, and that was the only uncontrollable variant in modern Portland cement production. Those strength variations, however, were also indicated in the works production records, but not to the extent shown in Table 1. It would have been of interest if the mean-strength and heat-of-hydration values had been included in that Table.

The cement manufacturers' results for their portions of the official sixty-nine samples tested, including mean values for strength and heat of hydration, were shown in Table 9.

According to that Table all the sixty-nine samples and means exceeded the requirements of B.S. 1370 ("Low-Heat Cement") for strength at all three test periods and the heat-of-hydration values were well below the specified limits.

Mr R. A. I. Irvine observed that the Claerwen Dam would increase the water supply for Birmingham to about 75 million gallons per day, but if consumption continued to rise by 1 million gallons per day each year as it had risen since 1937 (when it was 34 million gallons per day), then by 1978 the consumption would equal the yield. On that assumption, additional storage would be needed in 25 years' time.

TABLE 9

Age : days	B.S. 1370 requirement : lb./sq. in.	Actual strength		Mean values : lb./sq. in.	Heat of hydration mean values : calories per gram of cement	B.S.1370 max. limits : calories per gram of cement
		min. lb./sq. in.	max. lb./sq. in.			
3	1,000	1,150	2,662	1,775		
7	1,600	2,000	3,650	2,559	51·6	65
28	3,750	4,025	6,450	4,934	63·0	75

The dam had been built 184 feet high, but from the Paper it appeared that the dam would have had to be 200 feet high to have extracted the full yield from the Claerwen Valley, and at a rough estimate, the extra cost would have been about 12½ per cent of the initial outlay. The potential yield of the catchment area above the dam was about 45 million gallons per day, based upon a run-off of three-quarters of the long-term annual average rainfall, and a catchment of 13,910 acres. The new dam was designed to abstract 30 million gallons per day, and so there was an untapped yield of 15 million gallons per day. Assuming that that could have been conserved for 12½ per cent extra outlay, the need for additional storage would have been postponed for a further 15 years, that was, for 40 years in all. No reasons were given for the reduction in the height of the dam—they might well have been financial reasons or perhaps biological reasons. But if the former, then it was worth while considering whether the maximum yield could have been obtained for the same initial outlay, with a higher dam of another type.

However, it had been decided that the new work should harmonize, and be in keeping, with the high standard of the old dams, and that decision seemed to have predetermined the type of structure, for the only type which would so conform was the masonry-faced gravity dam. The massive buttress design was thereby ruled out. It was difficult to say what design the engineers might otherwise have favoured, and it would be interesting if the Authors would give their views as to whether ground conditions were favourable to a buttress dam or not, having regard to the crushing strength of the foundation rock. Such a dam was cheaper by about 20 per cent to construct than the gravity dam of equal height, because of the reduction in volume of concrete and the substitution of the cheaper ordinary cement for low-heat cement. Moreover, reduction in uplift under the base, and of temperature stresses in the concrete, contributed to easier design. Thus, if the buttress type of dam could have been accepted, then one 200 feet high might have been built for no more than the original estimate, and that would have postponed for 40 years, instead of 25 years, the need for additional storage.

Another possibly cheaper alternative to the ordinary gravity dam was the narrow gravity section with vertical prestressing cables through the dam anchored to the rock below the foundations. That, however, might seem very advanced design, and the Authors' views as to its suitability would be interesting.

In the same way, the shape of the spillway also seemed to have been predetermined, and with it the need for the bridge of thirteen arches to carry the roadway. The spillway was longer than given by the rule of 3 feet per 100 acres of catchment, by which the length would have been 417 feet, but a much greater reduction in length would have been necessary in order to effect a great saving on bridge construction. Might not the use of two drum gates such as were operating at Pitlochry have shortened the length to be bridged? Those gates were designed to discharge 40,000 cusecs, the width of each gate being 90 feet. The maximum flood to be discharged by the Claerwen spillway was 5,800 cusecs, so that possibly one gate about 30 feet wide would have achieved the required purpose. Allowing, however, for two gates and their abutments, the length to be bridged would be reduced to about 100 feet in two spans. If that could have been done, some further saving might have been made which would have contributed to the cost of increasing the height of the dam, and so increasing storage. In that case, the need for the masonry facing to the whole of the downstream surface of the dam could then have been obviated.

A second alternative to the spillway on the crest was the double spillway at right angles to the dam, similar to the one constructed at the Blithfield reservoir for the South Staffordshire Waterworks Co., to the design of Mr H. P. Hill, M.I.C.E. Since the flood was discharged over two parallel weirs, the overall projection into the reservoir was only half the length of the crest spillway. Furthermore, it could be located anywhere along the dam, and so need not be a costly structure. If such a spillway had to be constructed in reinforced concrete, no doubt a way could be found to protect the structure from the acid waters of the district. It would be interesting to learn if alternative forms had in fact been considered.

With regard to the design and construction, the maximum vertical stress at any horizontal plane was not to exceed 10 tons per square foot. Nevertheless, the dam had been built initially with a reduced cross-section, and when masons had become available, the remainder—faced with masonry—had been added at a later stage to the downstream side (the region of greatest stresses). It was difficult to see how an effective bond at the vertical joint between the two masses of concrete could be made, because of the large size of the aggregates, without special measures. Would the Authors give more information as to what had been done, for on the information given in the Paper, the added portion could not contribute to the strength of the dam, and therefore compressive stresses might exceed the limit laid down.

The choice of Pennant stone for the downstream facing appeared to have been as arbitrary as that of the Derbyshire Gritstone for the tail race walls etc., but might have been dictated by labour conditions. If so, it was to be hoped that an engineering approach to the matter would confirm the choice. How had the Contractors intended to build the in-situ downstream masonry facing at the maximum slope of $1\frac{1}{2} : 1$ and yet maintain the speed of concreting evidently visualized in the tender ? The problem became easier when it was permitted to build the masonry subsequent to the main concrete, although it was interesting to note that the masonry ultimately overtook the concreting when the volume of lifts in the body of the dam became much smaller. The building of masonry and placing of backing concrete had evidently been accelerated greatly, which led one to enquire if temperatures were recorded in the backing.

The centre spillway crest had been designed by the use of models, but the design had not been continued throughout the whole length of the spillway, and no reason was given for the discontinuity of design.

It was stated that control of the concrete had proved difficult owing to the nature of the aggregates, so it was not easy to see why a further sub-division of the aggregates would have assisted in control. Would not the elimination of one of the lower sizes have been a better course to take, resulting probably in lower water/cement ratio ? When 6-inch-maximum-size stone had been substituted for $2\frac{1}{2}$-inch-maximum-size, had the Contractors reconsidered the type of vibrator they had previously proposed to use ? The frequency, acceleration, output, and number of vibrators used in the lift was not stated, but at water/cement ratios above 0·62 with the use of Teepol, or 0·70 without Teepol, one would regard vibrators not as compacting agents but only as placing agents. No detail was given of the method of bonding the upper layer of concrete to the one below, and again unless special measures were taken having regard to the large-size aggregate, it was difficult to say how effective was the bond, especially since on two occasions, when injecting grout into a hole drilled through the concrete down into the foundations, the grout had penetrated between two layers of concrete and tended to lift the upper layer.

The cableways had served the work very elegantly, but it was inferred from the Paper that four mobile cranes also had been required, probably all engaged on masonry, shuttering, and the like, while four derrick cranes had also been used on the dam itself. Had the masonry facing been laid prior to the main lifts of concrete instead of afterwards, more mobile cranes would have been required.

On the Loch Sloy Dam, two cableways had been used, also assisted by four derrick cranes, and that dam had no masonry facing. Thus it seemed if cableways were used, there would always have to be two of them, and they would always have to be assisted by many cranes. Moreover, the span of the cableways limited their utility for future work, whereas derrick cranes were very versatile tools. No doubt the short span of the cableways,

coupled with the possibility of delays to derricks by wind, had decided in favour of cableways, but Mr Irvine did not think the choice was quite so clear-cut as had recently been made out. A double-track gantry, curved in plan, about 40 feet below crest level, and carrying four travelling derricks, would have served the scheme equally well, and perhaps more economically than two cableways assisted by a minimum of four derricks.

When compared with the other dams in the Elan Valley, the new dam did not exhibit the strides taken by civil engineers in the past half-century ; nevertheless it was a notable addition to Birmingham's Waterworks, and would serve, by the creation of its reservoir, to beautify the rather bleak stretches of the upper catchment area of the Claerwen.

Mr N. S. Boulton observed that the method of design described in the Appendix was said to be " . . . more rational for high gravity dams than the ' middle-third rule '." The justification for departing from that long-established rule would seem to be that tension cracks in the water face were permitted, provided that a full allowance was made for the hydrostatic pressure acting in those cracks. Such an allowance was made in the design described by the Authors. The assumed pressure, however, ranged from maximum at the water face to zero at the downstream face, whereas it could be argued that the full upstream pressure should be allowed over that part of the cross-section near the water face which was not under vertical compressive stress.

The vertical drains and the tensile strength of the concrete then provided some margin of safety against the tension cracks occurring under normal working conditions.

In arriving at the most rational design procedure, the proportion of the seepage pressure in the body of the dam which was relieved by the vertical drains was important. It could be estimated on the assumption that the seepage flow occurred in horizontal planes and that the permeability of the concrete was uniform. The pressure relief depended primarily upon the ratio of the distance between drain-centres to the width of the dam at the level considered.

The seepage pressure on a horizontal line through the centres of the drains had a maximum value midway between two consecutive drains. For the cross-section shown in *Fig. 8 (b)*, the reduction in the maximum pressure at 1,198 O.D., near the top of the dam, was negligible. Hence, since at that level the drain was almost at the mid-point of the section, the seepage pressure was 50 per cent of the hydrostatic pressure at the water face.

On the other hand, at level 1,030 O.D., near the base of the dam, calculation showed that the maximum seepage pressure at the drain line was only 24 per cent of the hydrostatic pressure acting at the upstream face.

If, for simplicity, linear variations in seepage pressure were to be assumed from the water face to the drain and from the drain to the down-

stream face, it would be found that the seepage pressure was always overestimated, showing that that was a conservative assumption.

The above values for seepage pressure were correct only if the permeability of the concrete was uniform. If the permeability along construction joints, or elsewhere, was greater near the upstream than near the downstream face, the seepage pressures would be considerably greater. Such adverse variations in permeability were, however, only likely to occur in comparatively short lengths of the dam. Moreover, the stresses produced by those increased seepage pressures would be distributed over a much greater length of dam than that acted upon by the increased pressure. Therefore, a sufficiently conservative allowance was probably obtained if only one-half of the pressure relief based upon uniform permeability was used. For the drains spaced at 15-foot centres, the allowance would then range from 75 per cent of full hydrostatic pressure at the drain line near the top of the dam, to 62 per cent at the drain line near the base.

Adopting that allowance for seepage pressure, the cross-section should then be designed, in Mr Boulton's opinion, by the middle-third rule, down to a level at which the allowable compressive stress was reached. Below that level, the profile would be designed for constant vertical compressive stress at the toe or, alternatively, for constant principal compressive stress.

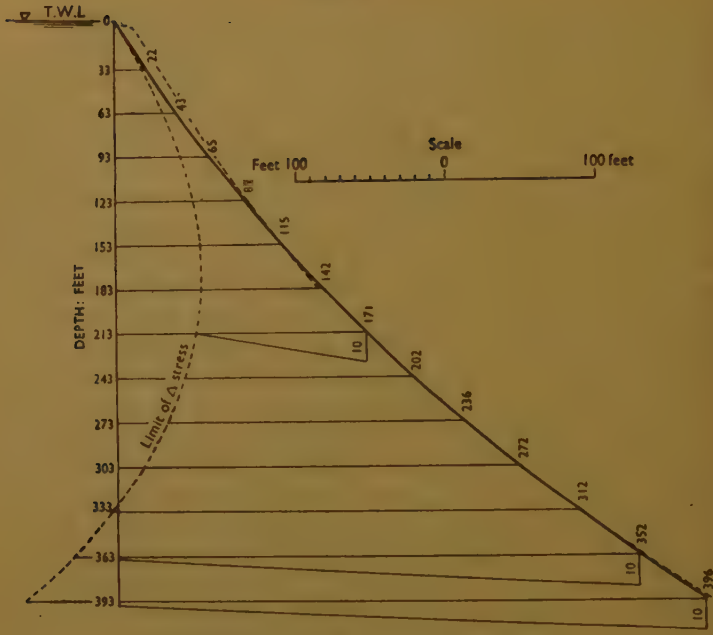
With reference to the model-experiments mentioned in the Paper, the maximum head on Model I was apparently only 0·75 inch ; hence, some scale effect was to be expected. It would be of interest to know if such an effect was observed when the results for Models I and II were compared.

Professor A. H. Naylor suggested that it might be of interest to reproduce the profiles arising from the formulae in the Appendix to the Paper. *Fig. 24* showed the profile for the case of full triangular uplift, the Claerwen profile being indicated in dotted lines. *Fig. 25* gave the profile without uplift. In both cases, the density and the vertical stress were the same as that given in the Paper, namely, 140 lb. per cubic foot, and 10 tons per square foot.

Those profiles, which had been evolved in 1930, had rightly been superseded by more accurate methods of stress analysis. They were also open to the objection that the maximum stress on the downstream face, which equalled the vertical stress multiplied by the secant squared of the angle of the batter, was not constant but increased slowly with depth, so that in a very high dam that increase might be substantial. Nevertheless, as Mr Morgan had pointed out, it was useful for preliminary design. A pleasing profile resulted, and if an appropriate maximum principal stress were selected, it would err on the safe side.

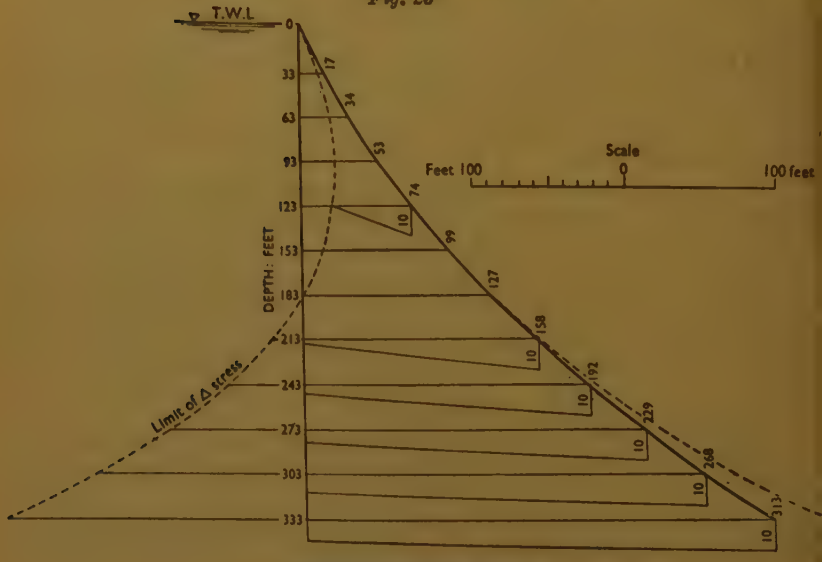
It would be noted from *Fig. 24* that at a depth of 330 feet the triangular distribution of pressure reached the face, so that below that depth the formula was no longer strictly applicable. The resultant trapezoidal distribution of stress brought the profile within the theoretical curve as shown. In the case of the dam shown in *Fig. 25*, with no uplift, the

Fig. 24



PROFILE WITH TRIANGULAR UPLIFT

Fig. 25



PROFILE WITHOUT UPLIFT

transition point was at a depth of 180 feet. It was interesting to note that at a depth of 330 feet, both designs, with or without uplift, gave the same width of 310 feet for a maximum vertical stress of 10 tons per square foot.

The assumption of triangular uplift pressure was not strictly compatible with the assumption of no tensile strength. The latter assumed elastic deformation in compression and an opening of the horizontal joints in tension. The latter, if it occurred, would give full hydrostatic uplift to the end of the open joint. In a large dam there was a danger of opening along horizontal construction joints, because the upstream face cooled and shrank while the centre was still warm. In constant-maximum-stress design it was desirable that entry of the hydrostatic pressure into the horizontal joints should be prevented by copper strip or a horizontal bituminous seal.

If the maximum principal stress were to be adopted as a criterion for design, the provision of an upstream batter, as in the Wegmann profile and as provided in normal practice, became illogical, for even with a vertical upstream face, the maximum stress (reservoir empty) was less than the maximum principal stress in the downstream face (reservoir full). Moreover, one could afford to design to a smaller factor of safety for the condition of " reservoir empty." It was suggested, therefore, that upstream batter served no useful purpose except near the foundation. There, as exact stress analysis had shown, there was a concentration of stress which indicated the desirability of a rounded fillet of ample radius.

The Authors, in reply, agreed with the points made by Professor Naylor.

The contribution of Dr Zienkiewicz was a perfect example of the academical approach. That side of the civil engineering profession which was concerned with precept rather than practice was always anxious to reduce all problems to a mathematical formula true for all values of the various unknowns. Unfortunately that was seldom possible and the practising engineer had to be content at times with an analytical treatment which was correct only within the range of practical design. In the Authors' view it was obviously implicit in the constant stress formula that it was to be used for the preliminary determination of dam profiles in which the thrust was somewhere in the region of the middle third ; in that case the formula was quite accurate enough for the required purpose.

The assumption that there was no tension in the masonry was not new and it was well known that good masonry would withstand low tensile stresses, but since the degree of its ability to do so was not known it was convenient to assume that there was no tension. The Authors pointed out to Dr Zienkiewicz that the same fundamental assumption was made in the design of reinforced concrete but that did not imply that the engineer expected the concrete to crack throughout the tension side, otherwise he would not employ structures of that type under water. It was equally

unreasonable to assume that the assumption of no tensile stress made during the derivation of the constant stress formula implied that the dam would necessarily crack horizontally throughout the length of the upstream face and so to allow for hydrostatic pressure to be developed in such cracks. The practising engineer knew perfectly well that there was not likely to be any crack at all and that even if there were, hydrostatic pressure would be relieved by the drains placed close to the upstream face for that purpose.

It was correct and proper that those responsible for giving engineering students their technical training should be purists, so as to engender a proper respect for fundamentals. It should be remembered, however, that the young engineer had afterwards to learn by experience the sometimes limited extent to which assumptions made in accepted theory were valid. It was not always appreciated in academical circles, for instance, that as a material, concrete conformed somewhat erratically with Hooke's law, particularly in a structure like a gravity dam which was built slowly, in comparatively small increments.

In reply to Mr Gullen, the Authors had not intended to imply that the low-heat cement had proved anything but satisfactory. At the start of concreting the strength variations of the lean mix at early ages had caused some anxiety, especially on account of the introduction of other novel features such as large-sized aggregate and a wetting agent, and it was with a view to finding the cause of those variations that the plotting of the comparative chart (Fig. 12, Plate 1) had been started on the site.

Mr Gullen had always maintained that the low-heat cement concrete-strengths would reach those of a similar normal Portland-cement concrete at 9 or 12 months' age, and the figures given in Table 5 of the Paper confirmed his confidence.

The mean-strength values given by the laboratory tests on the low-heat cement were about 13 per cent lower than those shown by the works production records quoted by Mr Gullen in Table 9, but they were still substantially above the specified strengths :

Age	Actual mean-strength values
3 days . .	1,545 lb./sq. in.
7 days . .	2,248 lb./sq. in.
28 days . .	4,254 lb./sq. in.

On the question of storage and yield, Mr Irvine appeared to have misinterpreted the figures given on pp. 249, 251, and 252, which, for brevity, had been greatly condensed. The Claerwen Dam as built was 207 feet high, measured from broad foundation to crest level, and the storage it provided did develop fully the catchment area of 13,260 acres on the basis of equalizing the run-off (about 37 inches) of the driest 3 consecutive years. The reliable collectable yield was about 32 million gallons per day and there was no untapped yield as Mr Irvine suggested. An increase of

2 million gallons per day in the compensation water had to be given from the date of filling the new reservoir. If present trends continued, the City of Birmingham might have to look elsewhere to augment their supply in about 25 years' time. It might be noted that the total storage now provided was about 4,000 million gallons greater than that contemplated by Mansergh for his completed scheme.

The appearance of the structure and the profile of the spillweir crest had been designed to comply with the wishes of the client, who had long-standing records of the discharges over that type of crest, and for that reason the interesting alternative suggested by Mr Irvine had not been considered. The central stepped downstream face had been designed to accommodate the normal low flows, but since the steps involved more than 50 per cent greater volume of masonry compared with a plain face, they had not been extended over the face area below the flood crest, which was similar in design to the existing Elan dams.

On the subject of control and placing of the mass concrete, experience gained in the use of that type and size of aggregate had suggested other improvements which could be made in the screening lay-out, but owing to difficulties in obtaining plant at the time, the delays to progress which further modifications would have involved had not been considered justifiable.

In spite of the high water/cement ratios used, the mass concrete had had a very low slump and fairly heavy vibrators had been essential to achieve compaction, several types of vibrator being tried out. The CP.417 compressed-air tool, weight 55 lb., and the Allam, type E.F. Size " T ", electric-driven tool, weight about 40 lb., had been used with success; both of them operated at 7,500 vibrations per minute, the latter being used after the introduction of Teepol into the mix. Normally two tools had been adequate for compacting the concrete placed at an average rate of about 90 cubic yards per hour.

The large size of aggregate had made little difference to the usual method of bonding successive layers of concrete. Very little laitance had been produced and the surfaces had been cleaned while green by brushing and scouring with air/water jets. Before placing concrete to the subsequent lift a $\frac{1}{2}$-inch layer of 2-to-1 sand/cement grout had been spread over the surface with satisfactory results. The trouble referred to when the pressure grouting lifted an upper layer of concrete had occurred only in the cut-off trench, where the size of aggregate in the concrete was below 3 inches, and it had probably been caused by drilling through the top lift while it was still too green, thereby disturbing the joint between lifts.

In reply to Mr Irvine's question on the subject of building masonry prior to placing concrete hearting, the masonry facing had been built up in lifts supported on precast concrete props, piers built of mortar and stone spalls, and occasionally timber, which had been removed after the mortar had set and prior to concreting. During the seasons of 1951 and 1952

masonry had been set at the rate of 500 square yards per week over long periods, which was proportional on the average to 6,000 cubic yards of concrete per week. It should therefore have been quite easy to keep ahead of concreting, which had averaged very much less than 6,000 cubic yards per week.

Mr Irvine had also referred to a possible alternative scheme for construction, namely, a gantry and travelling derricks. That scheme had been considered with others at the initial stages and ruled out on the issue of cost. It had been estimated at the time of tendering that the gantry alone would cost upwards of £70,000, and since some of the structure would have had to be buried in the dam such a scheme had not appeared at all attractive. The cableways were not quite so limited in application as might appear ; for example they could, without alteration, be used on a span of 2,100 feet to lift 8 tons, though of course a new set of ropes would be required.

REPORT OF THE COUNCIL AND STATEMENT OF ACCOUNTS 1952–53 *

In presenting the Annual Report upon the state of the Institution the Council wish, in the first place, to take the opportunity afforded by the Coronation to record, on behalf of the members of the Institution, expressions of loyalty and congratulation to Her Majesty Queen Elizabeth II, who has graciously consented to become its Patron in succession to her father, the late King George VI. A loyal Address of congratulation couched in the following terms has been submitted to Her Majesty.

TO HER MOST EXCELLENT MAJESTY QUEEN ELIZABETH II

MAY IT PLEASE YOUR MAJESTY

We, on behalf of the members of the Institution of Civil Engineers, humbly offer our sincere congratulations on the occasion of Your Majesty's Coronation and our earnest wishes that your reign may be long, peaceful, and prosperous.

We recall with particular pride the fact that Your Majesty, before becoming our Queen, honoured the Institution by graciously accepting Honorary Membership, and that subsequently Your Majesty conferred upon the Institution your patronage, thus evincing a sympathetic understanding of the work carried out by Civil Engineers in the advancement of engineering science and in the art of directing the great sources of power in nature for the use and convenience of man.

We beg leave to assure Your Majesty of our wholehearted loyalty and devotion and we pray that Almighty God may grant Your Majesty health and strength to fulfil your onerous duties.

(signed) *H. F. Cronin,* President.

(signed) *E. Graham Clark,* Secretary.

SEAL

Meetings.—Eight Ordinary and twenty-eight Divisional Meetings have been held as compared with a total of thirty-two in Session 1951-52. In addition, two evenings were devoted to displays of films; and a Joint Meeting was held with the Institution of Mechanical Engineers and the Institution of Electrical Engineers, at which a Paper on " The Athlone Fellowship Scheme for the Practical Training in Industry of Canadian Engineering Graduates in Great Britain " was presented for discussion.

* Presented to the Annual General Meeting, 9 June, 1953. An account of that meeting is printed as an inset with this number of Part I of the Proceedings.—SEC. I.C.E.

A list of the Papers, Lectures, and Discussions of the Ordinary and Divisional meetings will be found in Appendix I.

The Opening Meeting of Session 1952–53 took place on the 4th November, when Mr H. F. Cronin, in his Presidential Address, dealt with the water supply of London. He referred to the first use of steam engines for pumping water, and then proceeded to trace the history of pumped water supply from the formation of the Water Companies to the present day. He reviewed the work of the various Committees and Royal Commissions, the Report of the General Board of Health of 1850, the Metropolis Water Act of 1852, the construction of the first reservoirs, the early days of the Metropolitan Water Board, and the present situation of, and possible future demands upon, the Board.

Awards for Papers.—The awards for Papers presented at Ordinary and Divisional Meetings in Session 1952–53 will be announced at the Opening Meeting next Session, but the awards for Papers printed in the Proceedings, with written discussion only, between January and December 1952, will be announced at the forthcoming Annual General Meeting.

Conferences.—*Conference on Civil Engineering Problems in the Colonies.* The third Conference of this series was held at the Institution from the 16th to the 20th June, 1952. The programme followed the general pattern of the previous Conferences and comprised Technical Sessions and visits to Works.

The following is a list of the Papers presented for discussion at the Technical Sessions :—

"The Need for Colonial Road Research," by H. W. W. Pollitt, B.Sc.(Eng.), M.I.C.E.

"Hydro-Electric Development in Uganda," by C. R. Westlake, M.I.E.E., and T. A. L. Paton, B.Sc.(Eng.), M.I.C.E.

"The Development of the Water Resources of Southern Rhodesia," by P. H. Haviland, B.Sc., M.I.C.E.

"Notes on Re-laying and Maintenance, Nigerian Railway," by E. J. B. Gahan, B.A., B.A.I., A.M.I.C.E.

"Rehabilitation of the North Borneo Railway," by H. Gatford, E.D., B.Sc., M.I.C.E.

"Development of Rural Water Supplies in Tanganyika," by L. L. R. Buckland, C.B.E., B.Sc.(Eng.), M.I.C.E.

"The Hong Kong Waterworks," by Leonard Jackson, B.Eng., A.M.I.C.E.

Round Table Conference on Highway Problems in the Colonies.—The Council, at the request of the Colonial Office, organized this Conference at the Institution on the 23rd to the 25th June, 1952, that is to say, immediately after the Conference on Civil Engineering Problems in the Colonies. At the Conference the Colonial Office, the Crown Agents to the Colonies,

the Road Research Laboratory, and Colonies were represented. It was not the aim of the Conference to formulate any definite conclusions but to discuss in a general manner certain items of particular interest to road engineers in the Colonies. A summary of the report of the Conference has been published.[1]

The Public Works and Municipal Services Congress and Exhibition, 3–8 November.—The Council sponsored two Sessions of this Congress, the general arrangements for which were made by the Institution of Municipal Engineers, by obtaining two Papers for discussion, namely, "House Foundations: The Short-bored Pile," by W. H. Ward, B.Sc.(Eng.), A.M.I.C.E., and H. Green, A.M.I.Mech.E., and "Sea Defences," by C. H. Dobbie, B.Sc.(Eng.), M.I.C.E.

Publications

Proceedings.—The new system of issuing Parts I, II, and III of the Proceedings has operated smoothly, and the numbers of subscribers to Part II and Part III have fully met the expectations upon which the scheme was based. It is estimated that, under the new arrangement, the quantity of matter available to members is 25 per cent greater than hitherto.

Géotechnique, the International Journal of Soil Mechanics, is now issued in a quarterly form, which is found to be satisfactory.

Railway Engineering Abstracts has continued to review monthly world literature on civil, mechanical, and electrical engineering applied to railways.

Dry Docks: Memorandum on Construction and Equipment.

1951 Supplement to the Bibliography on Soil Mechanics.

1951 Supplement to the Bibliography on Prestressed Concrete.

Standard Method of Measurement of Civil Engineering Quantities.

Report of the Conference on Civil Engineering Problems in the Colonies, 1952.

Engineering Divisions.—The Council have authorized the formation of a new Division under the title of Hydraulics Engineering Division, having for its objects the study and discussion of the occurrence and behaviour of water in nature, fluid mechanics, gauging of rivers, relationship between rainfall and run-off, interpretation of flood data, measurement and control of flow in rivers and from reservoirs, irrigation, land drainage, underground water, and allied subjects. The eight Divisions held twenty-eight meetings during the Session.

Visits were paid to the Port of Rotterdam, the Thames Tidal Model, and the Manchester Ship Canal (Maritime and Waterways Division); the S.B.A.C. display at Farnborough and civil engineering works at London Airport (Airport Division); the Road Research Laboratory (Road Division); Maple Lodge Sewerage Works (Public Health Division); Pitstone Cement Works (Structural and Building Division); and Folkestone Warren

[1] *Chartered Civil Engineer*, Mar. 1953, p. 11.

(Railway Division). Brief accounts of these visits have appeared in *Chartered Civil Engineer*.

It is stressed that registration is no longer necessary in the Divisions and that members of all classes are entitled to attend the meetings and to take part in the oral and written discussions.

Library.—During the year, 519 volumes were presented to the Library and 349 were purchased, making a total on the 31st March of 67,738 volumes and 18,684 pamphlets. 4,453 applications for the loan of books were dealt with.

The reorganization of the library has continued and approximately 85 per cent of the books in the Main Library have now been reclassified by the Universal Decimal system. The rearrangement of the books on the shelves is expected to be completed during the summer and considerable care has been taken with the details of the shelving of the books so that members may find the system simple to use. The advice of Professor W. Fisher Cassie, Ph.D., M.I.C.E., who is the representative of the Institution on the Civil Engineering Panel of the U.D.C. Committee, has been very helpful in this respect.

The Loan Library has been reorganized and a new system of issuing is in operation.

Preparatory work has been undertaken for the reorganization of the Upper Library, where the journals and periodicals are kept.

Bookings for the loan of films from the Film Library have totalled 151 and a number of members have availed themselves of the service which provides for the loan of lantern slides. Two new films and several slides have been added to the Library during the year.

The Council has decided to form a collection of postage stamps, of all countries, the designs of which depict civil engineering works, such as bridges, lighthouses, dams, etc. The Council record their gratitude to the Crown Agents for the Colonies who have presented a complete set of current stamps, the designs of which show civil engineering structures in the Colonies. It is proposed that a selection from the collection should be displayed in the Library and that the whole of the collection will be available for inspection by members on demand.

Local Associations.—During the year under review the Local Associations have continued their activities; brief accounts of these appear in Appendix II.

The Council approved the formation of a Hull and East Riding Branch of the Yorkshire Association and this Branch held five meetings in its first Session.

There have been some changes among the Honorary Secretaries. Mr E. H. Sidwell, on his return from abroad, took over from Mr R. D. Fitzgerald (Northern Ireland); Mr H. B. Sutherland (Glasgow and East of Scotland) handed over to Dr C. M. Moir, who has previously served as

Honorary Secretary; Mr Bernard Whitteron was, on moving to London, succeeded by Mr J. S. Raine (Northern Counties), and in the Tees-side Branch, Mr T. W. Calvert took over from Mr J. P. Wain. In the Yorkshire Association, Mr D. F. C. Goddard has succeeded Mr H. B. Roberts.

Awards made by the Council for Session 1951–52 for Graduates' and Students' Papers read before Local Associations included Miller Prizes to each of three Student Members of the Edinburgh and East of Scotland Association and to a Student Member of each of the following Associations: Northern Counties; Glasgow and West of Scotland; South-Western. In the North-Western Association a James Forrest Medal and Miller Prize were awarded to one Student Member and a Miller Prize to another.

The Vernon Harcourt Lecture "Practical Methods in Flood Protection" by Mr W. E. Doran, which had been delivered to the Association of London Graduates and Students, was repeated before the Edinburgh and East of Scotland; Midlands; South-Western; Southern; Northern Ireland; and Yorkshire Associations.

Overseas Associations.—The Malayan Association continued its activities under the Chairmanship of Mr H. M. Alexander. Mr J. H. C. Shakespear took over the Honorary Treasurership from Mr A. S. Gifford. Mr G. Egan was succeeded as Honorary Secretary by Mr D. E. Lampert. Mr Borough Copley in British North Borneo acted as Corresponding Secretary to the Association in that area.

Six meetings were held in Singapore but none in the Federation owing to the abnormal conditions prevailing locally. Visits included a further one to the new power station at Pasir Panjang, Singapore, which was attended by about forty members.

The formation of a Joint Overseas Group of the three Institutions has been agreed upon locally and formal requests for the approval of the respective Councils have been received. The proposed Group will be confined to the Colony of Singapore in the first place but will ultimately, it is hoped, be extended to include the Federation of Malaya.

The membership of the Victorian Association reached a total of 147 during the Session, which is an increase of about 20 on the figure for last year. The activities have included a joint Dinner and Reception with the sister Institutions of Mechanical and Electrical Engineers, and two film evenings, one of which followed a dinner for members and guests; at the other, ladies were present and a supper was served.

The Trinidad Branch of the West Indies Association has held several Ordinary Meetings and two visits to works, one of which was organized jointly with the local branches of the Institutions of Mechanical and Electrical Engineers. The Annual Dinner was also held jointly with these

Institutions and His Excellency the Governor, Sir Hubert Rance, G.C.M.G., G.B.E., C.B., and Lady Rance were the principal guests.

The formation of a Joint Overseas Group is under consideration locally and pending a decision a Graduates' and Students' Section of the Branch is being formed.

Mr D. D. Ash (Member of Council) has been the Chairman of the Branch and Mr C. Dupenois succeeded Mr E. G. Elcock as Honorary Secretary.

Joint Overseas Groups.—The activities of the Abadan Overseas Group remain in abeyance.

The Argentine Joint Overseas Group held several meetings and the subject of the inaugural address by the Chairman (Mr A. C. Towers, M.I.E.E.) was " Developments in Electrical Engineering." The books accumulated by the former local associations of these Institutions have been offered to La Plata University.

A Joint Overseas Group was officially formed in Hong Kong in December 1952. Mr S. E. Faber, A.F.C., B.Sc., M.I.C.E., was elected its first Chairman, and Mr J. J. Robson, A.M.I.C.E., Honorary Secretary.

The Association of London Graduates and Students.—During the past year the Council have approved new Rules for the Association, which now includes in its membership the class of Graduates.

The opening meeting was held on the 5th November, and the Chairman, Mr W. N. Hammond, read his Address on " Transport Developments and the Civil Engineer," the President being in the Chair. The Vernon Harcourt Lecture was delivered, on the 7th January, by Mr W. E. Doran, who took for his subject " Practical Methods in Flood Protection " ; four other meetings were held, at two of which informal addresses were given by invited speakers, the other two taking the form of discussions. A joint meeting was held with the Graduate and Student sections of the Institution of Mechanical Engineers and the Institution of Electrical Engineers, when a Paper on " Industrial Health Engineering " was read by Mr R. J. Sherwood, B.Sc.(Eng.), Grad.I.Mech.E.

Social activities started with an innovation in the form of an informal gathering when about 150 students (members of the Association and others) were shown round the Institution ; Mr David M. Watson gave a brief talk on the history and activities of the Institution and Mr W. N. Hammond dealt with the work of the Association. Other social events were smoking concerts, after two meetings, and a joint dance with the Graduate and Student sections of the Institution of Mechanical Engineers and the Institution of Electrical Engineers.

Seven visits were paid to works during the course of the Session, and a small party made a conducted tour of engineering projects in Holland during the summer.

Three Miller Prizes have been awarded to members of the Association : to Mr A. C. Allen, for his Paper " Power from Water—Some Notes on Hydro-

Electric Development"; to Mr W. H. J. Dobson, for his Paper on "The Ashford Common Works of the Metropolitan Water Board"; and to Mr Arthur Marsland for his Paper "The Use of Scale Models in Civil Engineering."

Mr David M. Watson, Vice-President, has continued to act as Consultative Member of Council to the Association.

Competition for the Institution Medal and Premium (Local Associations).—The first Competition for the Institution Medal and Premium (Local Associations) took place on the 15th October, 1952, at the Institution. The President (Mr Quartermaine) took the chair at the meeting which was attended by forty Students and Graduates.

The following four Papers were presented:—

"The Construction of a Sewer passing through an Extensive Pocket of Running Sand," by A. D. Anderson, B.Sc., Stud.I.C.E. (Edinburgh and East of Scotland).

"A Survey of the Development and Uses of Hydraulic Models in the Field of Civil Engineering," by J. D. Geddes, Stud.I.C.E. (Northern Counties).

"Design of Proposed New Sludge Jetty for Belfast Corporation," by M. E. McKee, Stud.I.C.E. (Northern Ireland).

"The River Dee as a Source of Water Supply for the Wirral Peninsula," by F. G. Johnson, M.Eng., Stud.I.C.E. (North-Western).

The three judges, Mr G. M. McNaughton, Mr David M. Watson, and Mr C. L. Champion, after expressing gratification at the high standard of of all the Papers presented, awarded the Medal and Premium to Mr F. G. Johnson of the North-Western Association.

The medal was presented to Mr Johnson by the President on the occasion of the Annual Dinner of the Association in Manchester.

The judges in their report expressed the hope that more of the Associations would be able to compete next year.

Elections and Transfers.—The Council have dealt with 914 applications for election during the Session, 827 of these being new applications. Twelve applications for election direct to full Membership have been considered, seven of which were approved by the Council.

Consideration has also been given to 97 applications for transfer from Associate Member to Member, of which 65 were new applications.

Of the candidates actually elected as corporate members, 65·3 per cent are graduates of a university, 16 per cent have pursued their engineering studies at technical colleges, and the remainder have studied for the Institution Examinations by other means.

Education.—Of the 914 candidates who applied for election (between 1st April, 1952, and 31st March, 1953), 77·3 per cent pursued their technological studies by full-time courses at universities or technical colleges,

which in the Council's view is the most advantageous means of obtaining professional engineering education.

The number of candidates who applied to attend the Common Preliminary Examination conducted by the Engineering Joint Examination Board was 97 for the October 1952, and 126 for the April 1953, Examinations.

The number of candidates who entered for the October 1952, Institution Examination and for the Professional Interview was 967, including 193 at 29 centres overseas. For April 1953, there were 1,039 candidates, including 204 at 32 centres overseas, making a total of 2,006 candidates for the year.

The Council are paying special attention to the conduct of the Professional Interview, because this test is comparatively new and is of a unique character so far as other professional bodies are concerned. From experience it has been found that, with benefit, small alterations can be made in the machinery of the test; for example, a candidate who has not worked on the drawing board for many years may have difficulty in finding drawings prepared by him during his earlier office experience. Therefore, the Council are permitting such a candidate (who must be over 40 years of age and with at least 15 years engineering experience) to submit a report of works upon which he has been engaged, illustrated by drawings which need not necessarily have been prepared by him. Further, where deemed necessary by the Interviewer, a second opinion can be called for and a candidate may be interviewed by two senior engineers. Clarification has also been made of the requirements for those who are research workers by profession.

The Council have continued, through the President, to maintain a close association with the Institutions of Mechanical and of Electrical Engineers on the subject of Higher Technological Education. The President was also a member of a deputation which met the Minister of Education to press certain considered views relating to engineering education in this field.

Conference on Engineering Education.—A Conference on Engineering Education was held in London in January at which the three major Institutions acted as hosts to the representatives from the Engineering Societies of Western Europe and the United States of America (EUSEC). All the countries who are members of EUSEC were represented at the Conference except Finland. The Working Sessions were held in the buildings of the three Institutions in turn and were devoted to an exchange of views of mutual problems. At the final Session of the Conference it was agreed to recommend to EUSEC that a second Conference on Engineering Education should be held in 1954, on similar lines, to continue the work begun.

During the Conference, visits were paid by the delegates to technical colleges, universities, and industrial organizations.

The Conference was without doubt very successful in achieving its

main purpose, which was the exchange of views on the different educational and training methods in the various countries.

Bayliss Prize.—For the April 1952, Examination, the Prize was awarded to Mr Stanislaw Bregosz, Stud.I.C.E., and for the October 1952, Examination, to Mr John Neville Martin, Stud.I.C.E.

Research.—During the year, two new Committees have been appointed and one Committee has been dissolved. One other Committee previously dissolved has been re-appointed. The following is a summary of the work of the Research Committee :—

Abstracting.—An *ad hoc* Sub-committee has been appointed to consider the need for an abstracting service to cover the whole field of civil engineering, and is reviewing the existing facilities available and the methods adopted by other abstracting services.

Compressed Air.—Agreement has been reached with the Ministry of Labour and National Service on that part of the Draft Regulations for work of Engineering Construction dealing with work in compressed air and diving.

Coast Protection.—The first interim report of the Committee was published in *Chartered Civil Engineer* in November 1952.

Engineering Bills of Quantities.—The work of this Committee has been completed and a Standard Method of Measurement of Civil Engineering Quantities has been published. The Standard replaces the Report of the Committee on Engineering Quantities which was first published in 1933.

Erosion of Earthen Banks.—The Committee has continued to collect data on the over-topping of earthen banks.

Hydraulics.—Three Sub-committees have been set up to prepare reviews of developments within the past 10 years in research on flow in closed pipes, flow in open channels, and rainfall and run-off.

Location of Underground Services.—The Report published in 1946 is now out of print and comments have been invited from various engineers and authorities for the consideration of the Committee which has been revived with a view to a revision of the Report.

Mechanical Properties of Aggregates.—The preparation of a Report by this Committee is in an advanced stage. The Report will deal with the testing of aggregates for use in structures other than roads.

Performance of Concrete-Mixing Machinery.—The results of further experimental work recently carried out at the Road Research Laboratory are being considered by the Committee.

Pile Driving.—The response of members to the request of the Committee for data on pile driving has been disappointing. The Committee is very anxious to obtain such data.

Prestressed Concrete Development.—A study has been made of existing structures in order to determine whether there has been any deterioration

or not. The Committee has also carried out a study of the economics of prestressed concrete. The Supplement to the Bibliography on Prestressed Concrete for the year 1951 has been published and Supplements for 1952 and 1953 are in course of preparation.

Quality of Concrete in the Field.—The work of this Committee is well advanced and a draft Report is being considered.

Sea Action.—Tests on timber started in 1949 at Colombo, Singapore, and Upnor, are continuing.

Soil Mechanics and Foundations.—The Supplement to the Bibliography on Soil Mechanics for 1951 has been published and the Supplements for 1952 and 1953 are in course of preparation.

Vibrated Concrete.—A considerable amount of data has been collected by this Committee and is being collated.

James Alfred Ewing Medal.—On the joint nomination of Mr A. S. Quartermaine, President 1951–1952, and Professor Adrian, President of the Royal Society, the Council have awarded the James Alfred Ewing Medal for 1952 to Professor John Fleetwood Baker, O.B.E., M.A., Sc.D., D.Sc., M.I.C.E. The Medal is awarded for specially meritorious contributions to the science of engineering in the field of research.

Codes of Practice.—Discussions on the possibility of forming within the British Standards Institution an organization to be responsible for initiating and preparing Codes of Practice in the field of Civil Engineering have continued. The discussions have been extended so as to include all Codes of Practice within the proposed organization.

No Code of Practice for which the Institution is the convening body has been published during the year.

The panel appointed to revise the Glossary of Highway Engineering Terms has completed its task and the final draft has been forwarded to the British Standards Institution.

Public Relations.—The Council reconstituted the Public Relations Committee with a smaller membership and two meetings have been held. Endeavours to ensure that engineers and engineering works receive proper and adequate mention in newspapers have continued and the results are considered encouraging.

Three Christmas Lectures for boys were arranged at the Institution as follows :—

Aerodromes for Civilian Jet Aircraft, by W. G. M. Anderson, A.M.I.C.E.
The "Comet" in Passenger Service, by A. C. Ponsford (of B.O.A.C.).
Testing a Jet Transport, by Peter Bois (a Test Pilot of the de Havilland Aircraft Company, Ltd),

and full attendances were recorded.

In addition, lecturers were arranged for several bodies who applied to the Institution for assistance in this respect.

Accounts.—The accounts for the year ending on the 31st March, 1953, which have been duly audited, are detailed in Appendix IV of this Report and may be summarized briefly as follows :—

The *Total Income* for the year amounted to . . . (as compared with £88,085 last year) including £437 for Income Tax recovered. Subscriptions, Entrance Fees, and Examination Fees totalled £85,772 (as compared with £84,872 last year), and Dividends and Interest received amounted to £2,189 (as compared with £1,976 last year).	£89,598
The *Total Expenditure* charged against the year's Income amounted to . . . . . (as compared with £86,643 last year).	£88,832
The *General Revenue Account* therefore results in a credit balance on the year of	£766
The *General Revenue Account Surplus* amounted to £23,593 on the 31st March, 1953, made up as follows :—	
Balance brought forward 1st April, 1952 . .	£22,827
Add Surplus for year to 31st March, 1953 . .	£766
	£23,593

Cash at Bankers and in hand amounted to £50,003 (compared with £38,063 last year) at the close of the financial year, owing to the receipt, as in past years, of a substantial proportion of the current subscriptions during the first quarter and to the recent redemption of an investment. This balance is required to finance expenditure during the remainder of the year.

The actual expenditure during the year on "Publications Account" amounted to £39,121 (compared with £32,036 last year), of which £26,811 represented the cost of the Proceedings, etc. This expenditure was relieved by credits for advertisements, sales, etc., of £16,673 (against £9,759 last year), leaving the net expenditure for the year at £22,448 (compared with £22,277).

The Repairs and Renewals Reserve credit balance has been reduced by £5,674 during the year, viz. from £15,256 to £9,582.

On Trust Funds Income Account there was received a total of £2,206 and the expenditure amounted to £2,127.

During the year, sums of £21 in interest and £28 for sales of reports, etc., have been credited to the research into the Deterioration of Structures exposed to Sea-Action.

Scholarships and Prizes.—C. C. Lindsay Scholarships were awarded to Mr J. A. Jackson and Mr R. K. D. Murphie, Studs I.C.E. William

Lindley Scholarships were awarded to Mr E. C. Farrell and Mr M. W. Knill, Stud.I.C.E. A Dennison Scholarship was also awarded to Mr L. N. B. Holden, Stud.I.C.E. With regard to the Charles Hawksley Prize, 1952, none of the designs submitted was considered to be of a sufficiently high standard to be worthy of the Prize.

Rockefeller Foundation Bursaries in Public Health Engineering.—During the year, the Institution accepted an invitation from the Division of Medicine and Public Health of the Rockefeller Foundation to administer, over a period of three years ending 1955, certain monies for use in providing bursaries for post-graduate study and research in Public Health Engineering in universities in the United Kingdom.

Applicants for these bursaries, who must be engineering graduates of a University within the Commonwealth, are considered by an Awards Committee set up to administer the funds. This year, of seventeen applicants, seven have been awarded bursaries; of these, four are pursuing post-graduate studies and three are carrying out individual research work.

Conversazione.—The Conversazione was held at the Institution on the evening of the 19th June, 1952, when 1,270 members and guests, with their ladies, were present.

Annual Dinner.—The Annual Dinner of the Institution was held on the 30th April, 1953, at the Dorchester Hotel, London.

Nominations and Appointments.—The following appointments have been made by the Council during the year :—

Mr J. Guthrie Brown	British National Committee, International Commission on Large Dams, World Power Conference.
Dr A. W. Skempton Dr L. F. Cooling	British National Committee, International Society of Soil Mechanics and Foundation Engineering.
Mr George Baxter, O.B.E.	Representative for Scotland on the Mining Subsidence Committee.
Mr C. E. Boast, O.B.E., M.C.	Ministry of Health Advisory Committee on Building By-Laws.
Mr F. S. Snow	Advisory Council on Building Research and Development, Ministry of Works.
Dr Guthlac Wilson, S.M. Mr Ralph Freeman, C.B.E., M.A.	National Consultative Council, Ministry of Works.
Mr L. Scott White, O.B.E. Mr W. C. Andrews, O.B.E. (Deputy)	District Surveyors' Examination Board, London County Council.

Mr A. S. Quartermaine, C.B.E., M.C., B.Sc.(Eng.)	General Board of the National Physical Laboratory.
Mr G. A. Wilson, M.Eng.	Permanent International Association of Navigation Congresses. Preliminary Committee on Depths in Seaports.
Mr F. S. Snow	Concrete Technology Advisory Committee, Imperial College of Science and Technology.
Mr H. R. Lupton, O.B.E., M.A.	Advisory Committee on Machine Shop Engineering, City and Guilds of London Institute.
Dr Guthlac Wilson, S.M.	Governing Body of the Institute of Technology, Loughborough.
Mr A. B. Porter	Supreme Governing Body of the University of Liverpool.
Mr Ralph Freeman, C.B.E., M.A.	Governing Body of the South-East London Technical College.
Mr H. J. B. Harding, B.Sc. (Eng.)	Governing Body of Westminster Technical College.
Mr H. J. B. Harding, B.Sc. (Eng.) Mr G. A. R. Sheppard, M.A.	Regional Advisory Council, Regional Academic Board for London and Home Counties.
Mr N. S. Boulton, M.Sc.	Building Advisory Committee, College of Commerce and Technology, Sheffield.
Mr J. L. Beckett	Engineering Trades Advisory Committee, College of Technology, Leicester.
Mr N. A. Matheson	Northern Area Engineering Advisory Sub-Committee, Regional Council for further Education for the North-West.
Mr J. Paton Watson, C.B.E.	Southern Area Engineering Advisory Sub-Committee, Regional Council for further Education for the South-West.
Mr Arthur Floyd, C.B.E., B.Sc. Dr Guthlac Wilson, S.M. Mr R. M. Wynne-Edwards, D.S.O., O.B.E., M.C., M.A.	Board of the Professional Engineers Appointments Bureau.

International Engineering Congresses.—The British National Committee of the Permanent International Association of Navigation Congresses has sponsored the presentation of six Papers from Great Britain at the forthcoming International Congress in Rome in September 1953.

At the request of the International Association, the British National Committee has set up a Special Committee to study the depths of water to be provided in seaports in relation to the trend of shipbuilding as regards the dimensions and speeds of vessels. In addition to the Institution, the following bodies are represented on the Special Committee : the Institution of Naval Architects ; the Dock & Harbour Authorities' Association ; the Docks and Inland Waterways Executive ; the Shipbuilding Conference ; the United Kingdom Chamber of Shipping ; the Department of Scientific and Industrial Research ; the Ministry of Transport ; and the Admiralty.

The British Section of the International Society of Soil Mechanics and Foundation Engineering has held four Informal Meetings at the Institution. A feature of these meetings which has proved most successful is the discussion of articles published in *Géotechnique*.

The British National Committee has forwarded twenty-two Papers to Switzerland for presentation at the Third International Conference of the Society which is to be held in that country in August 1953.

Whilst membership of the British Section of the International Commission on Irrigation and Drainage is still small, the Committee was well supported by the members in the submission of items for publication in the Annual Bulletin.

The Second International Congress on Irrigation and Drainage is to be held in April 1954 in Algiers. The British National Committee is arranging for the participation of this country, and it is anticipated that the full quota of Papers permitted from this country will be taken up.

The Fourth International Congress of the International Association for Bridge and Structural Engineering was held in Cambridge and London in August/September 1952. The Institution serviced the General Purposes and Finance Committee and was represented on all the principal Committees set up to organize the Congress. The Institution undertook complete responsibility for the preparation of the Preliminary Publication and the Final Report of the Congress. The Institution also provided some of the personnel for the secretariat both in Cambridge and London.

Visit to the United States and Canada.—In September last, the Presidents and Secretaries of the Institutions of Civil, of Mechanical, and of Electrical Engineers attended the Centennial of Engineering in Chicago at the invitation of their American sister societies, particularly the American Society of Civil Engineers, whose 100th anniversary in 1952 was the reason for the Centennial. While the party was in New York a two-day round-table Conference was held, in which matters of interest to the six Societies were discussed. The return journey was made through Eastern Canada, thereby enabling the delegation to meet members of the Institution as well as members of the Engineering Institute of Canada in the Provinces of Ontario and Quebec.

The Roll.—The Roll of the Institution on the 31st March, 1953, stood at 19,170, the changes which had taken place in it during the year ended on that date being shown in the following Table.

	1 April, 1951, to 31 March, 1952						1 April, 1952, to 31 March, 1953						
	Honorary Members	Members	Associate Members	Associates	Students	Totals	Honorary Members	Members	Associate Members	Associates	Graduates	Students	Totals
umbers at commencement	16	2373	9416	36	5997	17,838	17	2379	9881	34	..	5843	18,154
ransfers—													
Associate Members to Members	..	+82	-82	..	..		..	+82	82	..	..	..	
lections	2	7	703	..	..	+1688	1	6	545	1	..	..	+2994
dmissions	..	..	..	..	947		..	..	..	..	1536	890	
estored to Roll	..	3	18	..	8		..	1	10	..	..	4	
eceased	1	66	89	2	8		1	62	67	1	..	8	
esigned	..	17	60	..	79		..	15	69	..	2	64	
ased	..	3	25	..	50		..	1	29	..	..	54	
ected as Associate Members	..	..	..	..	249		..	..	..	..	13	164	
dmitted as Graduates	..	..	..	..	..		..	..	..	..	..	809	
emoved over-age	..	..	..	..	712	−1372	..	..	..	..	..	610	−1978
iled to complete :—													
Transfer	..	..	..	..	..		..	..	..	..	..	..	
Election	..	..	..	..	..		..	..	1	..	..	..	
dmission	..	..	..	..	11		..	..	..	..	4	3	
						+316							+1016
umbers at ermination	17	2379	9881	34	5843	18,154	*16	2390	10188	34	1517	5025	19,170

* H.M. Queen Elizabeth who, prior to her accession, was an Honorary Member, has consented to become Patron of the Institution.

The full list of deaths and resignations is given in Appendix III, and the Council record with especial regret the deaths of Sir David Anderson, LL.D., B.Sc., Sydney Bryan Donkin, Professor Sir Charles Edward Inglis, O.B.E., M.A., LL.D., F.R.S., and Sir Leopold Halliday Savile, K.C.B. (Past-Presidents). The Council also record with regret the deaths of the Right Hon. Lord Macmillan of Aberfeldy, P.C., G.C.V.O., Q.C., (Hon. Member), Alfred Charles Gardner, F.R.S.E., Guthlac Wilson, S.M., D.Sc.

(Members of Council), James Cross, Herbert Hamer, and John Wood, C.M.G. (former Members of Council).

Acquisitions.—The Council have received, on behalf of the Institution, a portrait of Mr A. S. Quartermaine (President 1951–52) painted by Maurice Codner, R.P. A cherry-wood snuff box, which formerly belonged to I. K. Brunel was presented by Mr W. L. Raynes. Documents and a medal which belonged to his grandfather, William Lindley, M.I.C.E., a pioneer of sewage work in Germany, 1838–1879, were given by Mr E. S. Lindley, M.I.C.E. A silver salver which was presented to her father, the late Alfred Upward, M.I.C.E., for saving life in a fire, was bequeathed by the late Miss C. L. Upward.

APPENDIX I

ORDINARY MEETINGS

Presidential Address of Mr H. F. Cronin, C.B.E., M.C., B.Sc.(Eng.).

"Creep of High-Tensile Steel Wire," by N. W. B. Clarke, M.Eng., M.I.C.E., and Francis Walley, M.Sc., A.M.I.C.E.

The Unwin Memorial Lecture on "The Development and Functions of the Research Department of the Railway Executive," by T. M. Herbert.

"The Claerwen Dam," by H. D. Morgan, M.Sc.(Eng.), M.I.C.E., P. A. Scott, B.Sc., M.I.C.E., R. J. C. Walton, M.I.C.E., and R. H. Falkiner, B.A., B.A.I., A.M.I.C.E.

"Modern Developments in Surveying Methods and Instruments," by Alfred Stephenson, O.B.E., M.A., F.R.I.C.S.

"Special Features of the Affric Hydro-Electric Scheme (Scotland)," by C. M. Roberts, M.I.C.E.

"Scale-Model Experiments on High-Head Siphons and Vortex Chambers connected thereto," by Wilfred Eastwood, B.Eng., Ph.D., G. A. Taylor, M.A., B.Sc.(Eng.), Ph.D., A.M.I.C.E., and Professor Jack Allen, D.Sc., M.I.C.E.

"Wood Preservation," by N. A. Richardson, B.Sc.

The James Forrest Lecture on "The Impact of Statistics on Civil Engineering," by Professor H. Levy, M.A., D.Sc.

AIRPORT ENGINEERING DIVISION MEETINGS

"The Organization of Airport Construction," by E. A. Palmer.

"The Reconciliation of Civil Engineering Problems with International Standards in the Siting and Planning of Airports," by A. Shaw Maclaren, M.A., M.I.C.E.

"Methods of Soil Stabilization and their Application to the Construction of Airfield Pavements," by D. J. Maclean, B.Sc., and P. J. M. Robinson, B.Sc.(Eng.), A.M.I.C.E.

HYDRAULICS ENGINEERING DIVISION MEETING

"The Lynmouth Flood of August 1952," by C. H. Dobbie, B.Sc.(Eng.), M.I.C.E., and P. O. Wolf, B.Sc.(Eng.), A.M.I.C.E.

MARITIME AND WATERWAYS ENGINEERING DIVISION MEETINGS

"Some Designs for Flexible Fenders," by D. H. Little, B.Sc.(Eng.), A.M.I.C.E.

"The Reconstruction of Greenwell's No. 1 Dry Dock and Ancillary Works at Sunderland," by Harry Ridehalgh, M.I.C.E.

"Port of London Authority Engineering Works, 1952," by G. A. Wilson, M.Eng., M.I.C.E.

Lecture on "Echo Sounding in Relation to Modern Harbour and Coastal Surveys," by Commander D. H. Macmillan, R.N.R., F.R.I.C.S., F.I.N.

PUBLIC HEALTH ENGINEERING DIVISION MEETINGS

Lecture on " The Sardinian Project: an Experiment in Malaria Control by Species Eradication," by J. A. Logan, D.Sc.

" The Storage, Collection, and Disposal of Domestic Refuse," by J. C. Dawes, C.B.E., M.I.Mech.E.

" Controlling Factors in the Choice of Sewage-Treatment Processes," by W. Fillingham Brown, B.Sc.(Eng.), M.I.C.E.

" Bacteria in Relation to Water," by E. Windle Taylor, M.A., M.D., D.P.H., M.R.C.S., L.R.C.P.

RAILWAY ENGINEERING DIVISION MEETINGS

" Some Major Problems in Railway Civil Engineering Maintenance," by A. H. Cantrell, B.Sc.(Eng.), M.I.C.E.

" The Design of Structures in Relation to Maintenance and Inspection," by Frank Turton and N. S. Cox, B.Sc.(Eng.), M.I.C.E.

" The Trend of Development in Design and Equipment of Underground Railways," Part 1 (" A Review of Some Existing Systems ") by D. H. Coombs, B.Sc.(Econ.), A.M.I.C.E., A.M.I.Mech.E.

Part 2 (" Signalling ") by G. J. Willson, B.Sc.(Eng.), A.M.I.Mech.E., A.M.I.E.E.

" The Design and Equipment of Modern Marshalling Yards," by R. E. Sadler, A.M.I.C.E.

ROAD ENGINEERING DIVISION MEETINGS

" Soil Stability Problems in Road Engineering," by Rudolph Glossop, B.Sc., M.I.C.E. and G. C. Wilson, B.Sc.(Eng.), A.M.I.C.E.

" Some Aids to Traffic Flow," by R. A. B. Smith, M.C., A.M.I.C.E.

" Factors Affecting the Riding Quality of Machine-Laid Concrete Roads," by R. H. H. Kirkham, B.Sc., Ph.D., A.M.I.C.E.

" The Design of Motorways," by T. E. Hutton, B.Sc., A.M.I.C.E.

STRUCTURAL AND BUILDING ENGINEERING DIVISION MEETINGS

" The Design and Construction of the British European Airways Hangars at London Airport, with Particular Reference to Prestressed Concrete," by D. H. New, B.Sc.(Eng.), M.I.C.E.

" Corrugated Concrete Shell Roofs," by J. H. de W. Waller, D.S.O., O.B.E., M.E., M.Sc., M.I.C.E., and A. C. Aston, B.Sc.(Eng.).

" The Design of a Reinforced-Concrete Factory at Brynmawr, South Wales," by O. N. Arup, C.B.E., B.Sc., M.I.C.E., and R. S. Jenkins, B.Sc.(Eng.), A.M.I.C.E.

Discussion on " Would the Strength Grading of Ordinary Portland Cement be a Contribution to Structural Economy." Introductory Notes by F. S. Snow, M.I.C.E., F. M. Lea, C.B.E., D.Sc., Hon.A.R.I.B.A., L. J. Murdock, M.Sc.(Eng.), Ph.D., A.M.I.C.E., and Edward Burke, M.Sc.(Eng.), A.M.I.C.E.

WORKS CONSTRUCTION DIVISION MEETINGS

" Economic Use of Heavy Earth-Moving Equipments and Field Maintenance thereof," by B. J. Meighan, A.M.I.Mech.E.

" The Application of Precast Concrete to the Construction of Acton Lane ' B ' Power Station," by J. A. Derrington, B.Sc.(Eng.), A.M.I.C.E., and A. G. S. Lance.

" Construction of Tignes Dam and Malgovert Tunnel," by Jean Pelletier.

JOINT MEETING OF RAILWAY ENGINEERING AND WORKS CONSTRUCTION DIVISIONS

Lecture on " The Reconstruction of French Railways," by René Miot.

APPENDIX II*

GLASGOW AND WEST OF SCOTLAND ASSOCIATION

The Association sustained a grievous loss through the death of Mr A. C. Gardner (M.) in December 1952. Mr Gardner was Chairman of the Association from 1946 to 1948 and at the time of his death represented the Association on the Council of the Institution.

The inaugural Address of the Chairman, Mr Liston Carnie (M.), was delivered on the 10th October, 1952. The subject was "The Consulting Civil Engineer's Job." Mr Carnie selected for description some unusual jobs, illustrative of the wide range of a consulting engineer's work, in which his firm had been engaged. References to structural work and structural failures, marine salvage, the Mid-Scotland Ship Canal, and a humorous section entitled "Odds and Ends" formed a very interesting Paper. Incidentally, Mr Carnie is the fourth member of his firm to occupy the Chair during the past 62 years.

The Ordinary Meetings were outstanding for the widely contrasting nature of the subjects discussed. These ranged from problem jobs, as seen from contractors' viewpoints, to the life history of marine boring animals described by a Professor of zoology.

A meeting of the Association was held in Inverness in February 1953. Mr Brydon (M.), Vice-Chairman of the Association, occupied the Chair and Mr A. Leslie (M.) read a Paper on "Unusual Features in the Design and Construction of a Deep Furnace Pit."

The Students, under their Chairman, Mr John Paton (M.), included in their programme such items as "Shipbuilding and the Civil Engineer," "Control of Water in Large Volumes," and "Geological Aspects of Civil Engineering in the Scottish Highlands."

A Miller Prize was awarded to Mr D. F. Watson (S.) for his Paper "Soil Stabilization," presented last Session.

Two visits to works under construction were made during the session. One of these works was the deep furnace pit described in Mr Leslie's Paper and the other was a reinforced-concrete water-tower.

The Summer Meeting this year took the form of a Dinner-Dance in Loch Awe Hotel, Argyllshire, on the evening of the 15th May, followed by a full day on the 16th May at the site of the Glen Shira Project of the North of Scotland Hydro-Electric Board, at the kind invitation of Messrs Babtie, Shaw & Morton, the consulting engineers.

The Annual Dinner, held in November 1952, gave the President and the Secretary of the Institution an opportunity to meet some of the Scottish Members and Students. The speeches were of a high order and the 310 members and guests voted it a very successful evening.

The corresponding function for the Students, the Annual Joint Dance with the Institutions of Mechanical and Electrical Engineers, was held in February 1953.

NORTH-WESTERN ASSOCIATION

Mr C. G. Kent (M.) who, prior to his retirement in 1948, was Head of the Design and Construction Section of Manchester Corporation, succeeded Mr M. T. B. Whitson (M.) as Chairman of the Association for the 1952–53 Session.

In his inaugural Address, delivered at Manchester on the 9th October, 1952, Mr Kent described the large number of engineering works he had carried out during a career extending over more than half a century. He detailed the construction of main drainage schemes, road works, and sewage works. As engineer principally in charge of these works his experiences proved sometimes extraordinary, sometimes amusing, but always interesting. He deviated from his main theme to give excellent advice to the young engineer.

During the Session, eight meetings, in addition to the Chairman's Address and the Annual General Meeting, were held—six in Manchester, one in Chester, and one in Liverpool. Joint Meetings with the Liverpool Engineering Society (in Liverpool),

* In this Appendix the following abbreviations are used :— Member (M.) : Associate Member (A.M.) ; Graduate (G.) : Student (S.).

the Lancashire County Engineering Society (in Preston), the Reinforced Concrete Association (in Liverpool and Manchester), and the Institution of Structural Engineers, Lancashire and Cheshire Branch (in Manchester), have also been held.

The subjects dealt with were of a varied character and included " Water Conservation in Australia," " The Mulberry Harbour," " Recent Development in Concrete and Soil-Cement Roads," " Assignment to the United States Bureau of Reclamation," " The Practical Design of Rigid Frame Distillation Structures," " The Management of a Railway District Engineer's Office and some Reference to Permanent Way Design," " Design and Construction of a Six-Million-Cubic-Foot Gas-holder Foundation at Bristol," " Railway Electrification," " The Disarmament of Krupp, Essen," " Some Recent Foundation Research and its Application to Design," and " General Developments in Sewage Works Design."

The Students Section held a meeting in Manchester, at which six Students gave ten-minute talks on their experiences in the first years of professional employment. The meeting was attended by Students and Graduates of the Association and by university undergraduates, who contributed to the discussion which followed the talks.

A visit was paid to the British Electricity Authority's new Power Station at Carrington, Cheshire. The party included about 60 members of the Association.

The Association feels proud of the successes achieved by its Students. Mr F. G. Johnson (S.) was awarded the James Forrest Medal and a Miller Prize for his Paper " The River Dee as a Source of Water Supply for the Wirral Peninsula " and Mr J. R. Kemp (S.) a Miller Prize for his Paper " Some Considerations affecting Dock Design and Lay-out." Finally, in the first Competition held for the Institution Medal for Students of Local Associations, Mr Johnson was also successful.

The Annual Dinner was held at the Midland Hotel, Manchester, on the 12th March, 1953, at which the President and Secretary of the Institution were present. Among the guests were representatives of the scholastic, legal, and engineering professions in the North-West.

Mr R. J. Cornish (M.) was elected to the Council to represent the Association for the Session.

MIDLANDS ASSOCIATION

Mr C. A. Risbridger (M.), Chief Engineer to the Birmingham Water Department, succeeded Mr M. R. Vincent Daviss (M.) as Chairman. In his Chairman's Address, delivered in Birmingham on the 16th October, 1952, he followed the history of pipes used in water supply from the early eastern civilizations to the present time.

The Address was repeated by Mr Risbridger at meetings of the Association in Loughborough on the 29th October and in Nottingham on the 4th November.

During the Session, eight meetings were held in Birmingham, three in Loughborough, and two in Nottingham. In addition, one meeting was held jointly with the Institution of Mechanical Engineers and the Institution of Electrical Engineers, at which the attendance was about six hundred; a joint meeting was also held with the Institution of Structural Engineers.

The Papers dealt with highway design, water supply, prestressed concrete, shell concrete, soil mechanics, river work, dam construction, and dock work.

There were four Graduate and Student meetings, at three of which Papers were given by local Students, and in addition there was a joint meeting with the Graduates and Students of the local branches of the Institution of Mechanical Engineers and the Institution of Electrical Engineers and a joint meeting with the Students of the Institution of Structural Engineers.

During the summer months, a meeting was held at Coventry and afterwards at the Shakespeare Memorial Theatre, Stratford-on-Avon, at which ladies were present. Visits were also made to the Claerwen Dam, Stanton Ironworks, and Ketton Cement Works, the latter two visits being organized by the Students.

The Vernon Harcourt Lecture by Mr W. E. Doran (M.) was delivered before the Association in Birmingham.

The Annual Dinner of the Association was held at Birmingham on the 14th November, 1952. The President and Secretary of the Institution were present, and the Lord Mayor of Birmingham and the Vice-Chancellor of the University were the principal guests.

Mr C. A. Risbridger (M.) was appointed to the Council for 1952–53 to succeed Mr F. C. Vokes (M.), who had represented the Association for the past three years.

Mr R. R. W. Grigson (A.M.) has continued to serve on the Council.

NORTHERN COUNTIES ASSOCIATION

The Chairman, Mr D. M. O'Herlihy (M.), Engineer and Surveyor to the County Borough of Tynemouth, delivered his Chairman's Address at Newcastle, Middlesbrough, and Carlisle. He gave an account of works and developments with which he had been associated at Tynemouth.

During the Session, nine meetings were arranged by the Newcastle Branch. The subjects discussed at these meetings were :— Water Conservation in Australia ; A Dam Failure at Harrogate ; Harbour Design in South Africa ; Road Practice in America ; Welding ; Soil Mechanics in relation to the Structural Engineer ; Atmospheric Pollution in the United States ; and River Control.

Six meetings have been arranged by the Tees-side Branch and the subjects discussed were :—The Organization of a Large Civil Engineering Department ; Civil Engineering Design Work for Wilton Oil-Cracking Plant ; North Tees Power Station Construction ; and the Use of Plastics in Engineering.

Two meetings were held at Carlisle and one at Darlington.

Mr R. S. Cogden (A.M.) was again elected Chairman of the Students Section and six meetings have been arranged at Newcastle. The subjects discussed included :—Experiences in Civil Engineering Work ; The Errochty Hydro-Electric Scheme ; Caisson Bridge Foundations in France ; and Water Supply Problems.

The award of a Miller Prize to George Diggle (S.) for his Paper on "The Respective Merits of Cast-Iron and Steel Pipes in Waterworks Practice," which he presented last Session, has been announced.

About 260 schoolboys attended a Lecture on Hydraulic Engines given by the late Mr A. R. Fairburn. In September 1952 there were visits to the Broken Scar Waterworks at Darlington and the Codbeck Scheme at Osmotherly ; there was also a launch trip down the Tyne and an inspection of the new iron-ore quay at Tyne Dock.

In November 1952 the sea defence works at Silloth were inspected and in February 1953 a joint visit with the North-East Branch of the Institution of Mechanical Engineers was paid to the engineering works at Darlington.

A Dinner and Dance was held in Durham Castle on Wednesday, 7th January. About 240 members and guests attended.

The Annual Dinner was held at the Royal Station Hotel, Newcastle, on the 23rd April, 1953.

Mr S. G. Barrett (M.) was elected to represent the Association on the Council of the Institution for the Session.

YORKSHIRE ASSOCIATION

The 1952-53 Session opened on the 26th September, 1952, when the new Chairman, Professor R. H. Evans (M.), Professor of Civil Engineering in the University of Leeds, as successor to Mr H. Foster (M.), delivered his Address to a meeting held in Sheffield. The Address was also repeated at Hull on the 17th October, 1952. Professor Evans dealt with four main topics, namely, higher technological education ; training in industrial administration ; research in universities ; and the professional engineer and society.

During the Session, twelve Ordinary Meetings of Corporate Members, Graduates, and Students have been held, one meeting in Scunthorpe, one in York, two in Sheffield, three in Leeds, and five in Hull, in addition to the presentation of the Chairman's Address. Of these meetings one was held jointly with the Yorkshire branch of the Institution of Structural Engineers and one with the Northern Section of the Institution of Water Engineers.

The general standard of the attendance at these meetings has been good, the average for Association and Branch Meetings being approximately 70 and 45 respectively per meeting.

The subjects of the Papers presented during the Session have been diverse in their interest, and included two Papers on sewerage schemes, one on railway bridges, and the Paper on the Claerwen Dam which had been presented at the Institution in London.

The Vernon Harcourt Lecture by Mr W. E. Doran (M.) on " Practical Methods of Flood Protection " and an Address by Mr H. S. Waddington (A.M.) entitled " Engineering from an Office Chair " were delivered to meetings of the Branch in Hull.

At the Sheffield Meetings members heard Mr B. J. Meighan present his Paper on " Economic Use of Heavy Earth-Moving Equipments and Field Maintenance thereof " and two Papers by a Graduate and a Student respectively.

The meeting at Scunthorpe was arranged jointly with the Yorkshire Branch of the Institution of Structural Engineers and received a Paper presented by Mr F. A. Partridge (M.) on " The Plastic Theory and Its Application to the Design of Mild-Steel Beams and Rigid Frames."

In addition to the above meetings, five meetings of the Graduates and Students Section have been held. The programme included a visit to the Esholt Sewage Works at Bradford and the Steelworks of Steel, Peech and Tozer at Sheffield, Papers on "Some Experimental Methods for Determining Stress " by Mr B. L. Clarkson (S.) and Mr N. Jackson (G.) and " Timber as a Structural Material " by Mr J. Jowett. An evening was devoted to films of engineering interest.

The Session saw the completion of the arrangments for the formation of the Hull and East Riding Branch of the Association. The Council gave formal approval on the 16th December last to the revised By-laws incorporating the Branch.

The first Annual General Meeting was held on the 10th April, 1953, when the first full Branch Committee in accordance with the new By-laws was elected.

The Branch, as now constituted, includes in its area Kingston-upon-Hull, Scarborough, the East Riding of Yorkshire, and a small part of North Lincolnshire. The five meetings held in Hull were organized by the Branch.

The Annual Dinner of the Association was held at the Queen's Hotel, Leeds, on the 22nd April, 1953. The President and Secretary of the Institution were present and amoung the guests were the Lord Mayor and Lady Mayoress of Leeds, the Bishop of Ripon, the Pro-Chancellor and the Vice-Chancellor of the University of Leeds, the Vicar of Leeds, and Chairmen of kindred associations.

The Association has been represented on the Council of the Institution during the Session by Mr H. Foster (M.) who was the Chairman of the Association for the Session 1951–52.

SOUTH-WESTERN ASSOCIATION

Mr N. S. Cox (M.), who succeeded Mr. J. B. Bennett (M.) as Chairman, is the District Engineer for British Railways, Western Region, at Plymouth. His Address given in Bristol on the 9th October, 1952 and repeated in Plymouth on 13th November, covered some aspects of a District Engineer's duties, and described a few of the problems with which he is faced.

There were nineteen meetings during the Session, four of them held in conjunction with Local Associations of other Institutions. Three meetings took place at Plymouth and one at Exeter. The Papers presented covered many subjects, including water conservation in Australia, sewage treatment, road maintenance, soil mechanics, concrete mixes, flood protection methods, corrugated concrete shell roofs, etc. A Paper entitled " The Bristol Waterworks Tunnel at Cadbury Camp " was given jointly by Mr D. J. D. Wood (S.) and Mr R. J. Bradbury (G.) during the Students Evening held on the 12th February, 1953.

A Miller Prize was awarded to Mr E. W. Parkinson (A.M.) of the City Engineer's Department, Bristol, for his Paper on " The Proposed Fairfax Street Bridge, Bristol," and a certificate was presented to him during the opening meeting of the Session on the 9th October, 1952.

By kind permission of the South-Western Division of the British Electricity Authority, a visit was made from Bristol, Exeter, and Plymouth to the new Generating Station under construction at East Yelland, near Barnstaple, on Wednesday, 25 June, 1952. The party arrived on site immediately after lunching at Barnstaple, when the site engineers of Messrs Sir Alexander Gibb & Partners, together with representatives of the British Electricity Authority, showed members over the works. Another all-day visit, in conjunction with the South Wales and Monmouthshire Association, was made during October to Neath By-Pass and the new steel bridge under construction at Briton Ferry. In addition, a visit to the new 362-foot prestressed concrete footbridge at Whitleigh, Plymouth, took place in April of this year.

when members were enabled to see the falsework in position, the placing of precast units, and the stressing of the cables.

A combined Dance with the Institution of Mechanical Engineers, the Institution of Structural Engineers, and the Royal Aeronautical Society was held at the Royal Hotel, Bristol, on the 12th December, 1952.

The Annual Dinner of the Association was held on the 19th March, 1953, at the Royal Hotel, Bristol. The President and the Secretary of the Institution attended, and guests present included the Lord Mayor and Lady Mayoress, the Sheriff of Bristol and lady, and Chairmen of other Local Associations. The Dinner was followed by a Dance.

Mr G. Gould Marsland (M.) was again elected as the Association's representative on the Council.

NORTHERN IRELAND ASSOCIATION

Dr Denis Rebbeck (M.) succeeded Mr William Grigor (M.) as Chairman for the Session and delivered his Chairman's Address on the 20th October, 1952. Dr Rebbeck dealt with the history of shipbuilding over the past fifty years and illustrated his address with lantern slides.

Seven meetings have been held and the Papers included one on water supply by arrangement with the Institution of Civil Engineers of Ireland and one on reinforced-concrete building in Brazil, presented at a joint meeting with the Institution of Structural Engineers. At the Students Evening in February 1953, Mr M. E. McKee (S.) presented a Paper on the design of a proposed new sludge jetty for Belfast Corporation.

During the Christmas vacation three Lectures for schoolboys were arranged by the Association on the engineering services—water, gas, and electricity. The Lecturers were Mr R. E. D. Bain (M.), a Vice-Chairman of the Association, Mr T. Shillington of the local Gas Engineer's staff, and Mr P. Honey of the Electrical Development Association in London.

The Association co-operated with the Ministry of Health and Local Government in dealing with applications to attend two courses of Lectures on the production of high-quality concrete. The courses, of two days each, were given by Mr S. G. Boakes and Mr B. W. Shacklock of the Research and Development Division of the Cement and Concrete Association, and included demonstrations. The applications received were very numerous and about fifty of them could not be accepted owing to lack of accommodation.

The Vernon Harcourt Lecture on " Practical Methods of Flood Protection " was repeated by Mr W. E. Doran (M.) on the 20th April at Belfast.

The President and Secretary of the Institution were present at the Annual Dinner of the Association held in the Midland Hotel, Belfast, on the 12th February, when about eighty members and guests were present. The principal guest was the Prime Minister of Northern Ireland.

A successful social occasion in the form of a dance was held on the 20th March, 1953.

The attendances at meetings of the Association continued to be satisfactory, averaging as they did 92 out of a total strength for the whole of Northern Ireland of just less than 370.

Mr H. E. Campbell (M.), who had represented the Association on the Council for three years, was succeeded by Mr Robert McCreary (M.).

SOUTHERN ASSOCIATION

The Session opened on the 16th October, 1952, when Mr J. P. M. Pannell (M.), Engineer to Southampton Harbour Board, who succeeded Mr J. H. Jellett (M.) as Chairman, delivered his Address at Southampton. Mr Pannell's Address, entitled " The Birth of a Great Port," referred to the first fifty years of the Southampton Harbour Board which was formed by Act of Parliament on the 18th April, 1803. The Chairman dealt in particular with engineering works carried out by the Commissioners during the first fifty years on the recommendations of John Rennie and executed under the Surveyor to the Harbour Commissioners, John Doswell Doswell, who served the Board in that capacity for 51 years. The Address was illustrated by reproductions of old maps, prints, and records of the period covered.

During the Session, meetings were held at Southampton, Brighton, Portsmouth, Chichester, and Bournemouth. There were ten meetings in all, including two joint meetings with the South-Eastern District of the Institution of Municipal Engineers and one joint meeting with the Southern District of the Institution of Municipal Engineers. The general standard of attendance at these meetings has been good, the average being approximately 100 per meeting.

The Annual Summer Meeting last year was held in May. Mr and Mrs A. S. Quartermaine, together with the Secretary of the Institution, joined 90 members and guests for a visit to Winchester. The Annual Luncheon was served at the Polygon Hotel, Southampton.

Mr P. E. Sleight (M.) has again been nominated to the Council for 1953–54. He represented the Association for 1952–53.

SOUTH WALES AND MONMOUTHSHIRE ASSOCIATION

Mr R. O. Meek (A.M.), the Senior Drainage Engineer to the Swansea Corporation, was elected to succeed Mr Trevelyan Price (M.) as Chairman of the Association for the Session. Mr Meek delivered his inaugural Address at Cardiff on the 6th October, 1952; it was entitled "Some Historical Notes" and dealt with the history of the Institution.

Five ordinary meetings were held in Cardiff, two at Swansea, and one at Llanelly. The average attendances at these meetings was 65, and 104 members attended the Paper, "The Complementary Function of the Architect and Engineer" by Sir Percy Thomas, Past President of the Royal Institute of British Architects, and Mr W. S. Atkins (M.). Visits were made to the National Oil Refineries at Llandarcy, Carmarthen Bay Power Station, and the Neath By-Pass project; on the last visit the party was accompanied by some members of the South-Western Association. A joint visit with the Institution of Mechanical Engineers was made to the Cwmbran Development Corporation New Town and Swansea Outfall Sewage Works at Mumbles.

The Graduates and Students Section held three Ordinary Meetings and two visits to works. The Papers included one by Mr J. A. Gaffney (G.), the Honorary Assistant Secretary of the Association.

The Annual Ball was held at the Royal Hotel, Cardiff, during November 1952, and was very successful. This was the second Annual Ball of a series which is expected to become a regular feature of the programme for each Session.

The Annual Dinner of the Association was held at the Royal Hotel, Cardiff, on the 18th March, 1953, when the Association had the pleasure of the company of the President and Secretary of the Institution.

Lt-Col. R. H. Edwards (M.) continued to represent the Association on the Council for the Session.

EDINBURGH AND EAST OF SCOTLAND ASSOCIATION

The Chairman for the Session has been Mr Charles H. Smith (M.), Chief Engineer (Scotland) for Messrs George Wimpey & Co. Ltd, building and civil engineering contractors. He succeeded Mr A. A. Fulton (M.), Chief Hydraulic and Civil Engineer, North of Scotland Hydro-Electric Board. Mr Smith, in his inaugural Address on the 8th October, 1952, dealt with "Estimating," an essential duty, he said, for engineers and contractors alike but an onerous one in these days of fluctuating rates. As a definite illustration he took a simple reinforced-concrete wharf, supported on steel box-piles, which was to replace an existing timber wharf; the latter, still in service, supplied some of the estimator's problems such as, for instance, its capability of supporting the vibratory load of pile-driving plant, etc., and its orientation in regard to the new structure. The final result was detailed under three headings—dismantling the existing structure, erecting and dismantling the temporary structure, and piling and erecting the permanent structure. He stressed the importance of timing as affected by bottlenecks and the effect which one modification on design might have on the whole estimate.

The number of meetings held in Session 1952–53 was eleven. These included the inaugural meeting, the Annual General Meeting, two special Students meetings, and two outside meetings at Aberdeen and Perth respectively. The subjects dealt with at the ordinary meetings were The Atomic Research Extensions in Glasgow University, Earth Dams in the United States, Flood Protection (a repeat of the Vernon

Harcourt Lecture), A Pre-stressed Concrete Bridge at Bernera, and five Students' or Graduates' Papers, registered for the Miller Prize Competition. At the special Students meetings there were four short Student Papers on "Experiences in Practice" and a Paper by Dr. L. J. Murdock (A.M.) on "The Control of Concrete Quality." At the Aberdeen meeting the Paper on "Earth Dams in the United States" was repeated and at Perth the subject was "Geological Aspects of Hydro-Electric Projects."

The average attendance at the ordinary meetings was more than 90, the maximum being 124.

Miller Prizes were obtained by the three Student Members—Messrs Anderson, Haws, and Hope—who read Papers to the Association in 1951–52, and it is of interest to record, also, the award of Telford Premiums to Messrs A. A. Fulton and M. C. White (MM.) for Papers read to the Institution in 1951–52.

The Annual Dinner was held in November 1952 when members of the Association were pleased to welcome Mr H. F. Cronin as President. He had, as Senior Vice-Chairman, taken Mr A. S. Quartermaine's place at the 1951–52 Dinner and his return coincided with a record attendance of 124 members and guests.

Visits to engineering works continue to be a popular feature, recent visits being to Burntisland Shipyard, Rothes Colliery, Watch Water Reservoir, a coal-washing plant, and a shell roof in course of erection.

Two Christmas Lectures, under the auspices of the Institution, were given to more than 200 boys from secondary schools in Edinburgh, one by Mr C. W. Knight on "The Building of Dams," the other by Mr H. Shirley Smith on "The Wonders of Big Bridges."

Mr George Baxter (M.) completed his term of office as an ordinary Member of Council in September 1952, but Mr W. P. Haldane (M.) has continued to represent the Edinburgh and East of Scotland Association; he is now the only Member of Council resident in this area.

APPENDIX III

Deaths and Resignations

The full list of deaths is as follows (*e.* refers to election, *t.* to transfer, and *a.* to admission):—

Hon. Member (1).—*The Right Hon. Lord* Macmillan of Aberfeldy, P.C., *G.C.V.O.*, Q.C. (*e.* 1928).

Members (62).—*Sir* David Anderson, LL.D., B.Sc. (*e.* 1906, *t.* 1915) (*Past-President*); Ernest Barry (*e.* 1913, *t.* 1932); Percy Walter Bertlin (*e.* 1897, *t.* 1926); John Boyd Brodie (*e.* 1895, *t.* 1913); William Brown (*e.* 1915, *t.* 1947); John Braga Callander (*e.* 1922, *t.* 1930); Herbert Cawthra, *M.C.* (*e.* 1916, *t.* 1946); Raymond George Hubert Clements (*e.*1908, *t.* 1925); Vivian Bolton Douglas Cooper, *O.B.E.* (*e.* 1886, *t.* 1914); James Cross (*e.*1939, *t.* 1945) (*former Member of Council*); Harry Cunningham (*e.* 1903, *t.* 1920); David Alexander Davidson, B.E. (*e.* 1925, *t.* 1939); Sydney Bryan Donkin (*e.* 1898, *t.* 1912) (*Past-President*); Kenneth John Hier Evans, B.Sc. (*e.* 1927, *t.* 1936); Charles Henry Gale (*e.* 1889, *t.* 1913); Alfred Charles Gardner, F.R.S.E. (*e.* 1909, *t.* 1918) (*Member of Council*); *Col.* Frederick Harry Greenhough, *D.S.O.* (*e.* 1897, *t.* 1911); Herbert Hamer (*e.* 1912, *t.* 1933) (*former Member of Council*); Thomas White Harvie (*e.* 1904, *t.* 1924); Horace John Elliott Hone (*e.* 1910, *t.* 1936); Arthur Mumford Hughes (*e.* 1938); Joseph William Husband, B.Eng. (*e.* 1924, *t.* 1939); *Professor Sir* Charles Edward Inglis, *O.B.E.*, M.A., LL.D., F.R.S. (*e.* 1901, *t.* 1923) (*Past-President*); Gavin Heynes Jack (*e.* 1916); *Professor* Alexander Hope Jameson, M.Sc. (*e.* 1901, *t.* 1912); *Sir* Tom Barry Jones, *Bart*, M.A. (*e.* 1915, *t.* 1945); William Keay (*e.*1906, *t.* 1916); John Spencer Killick, *C.B.E.* (*e.* 1908, *t.* 1917); Douglas Hunter Laidlaw, B.A. (*e.* 1921); *Professor* Frederick Charles Lea, *O.B.E.*, D.Sc. (*e.* 1901, *t.* 1918); William Rowand McKim (*e.* 1914, *t.* 1938); William Dick McLaren (*e.* 1910, *t.* 1925); Nathaniel Martin, B.Sc. (*e.* 1910 *t.* 1943); Harry Powell Miles, *O.B.E.* (*e.* 1896, *t.* 1902); Stuart Kilsby Mobbs (*e.* 1912, *t.* 1935); Arnold Morris, *O.B.E.* (*e.* 1915, *t.* 1935); Edward Harold Morris (*e.* 1900, *t.* 1928); *Brig-Gen.* Magnus Mowat, *C.B.E.*, *T.D.*, F.R.S.E. (*e.* 1901, *t.* 1909); James Stilwell

Munce, B.E. (*E.* 1904, *T.* 1930); Charles Butterworth Newton (*E.* 1894, *T.* 1899); Nathaniel Pearce (*E.* 1906, *T.* 1922); Norman Augustus Victor Piercy, D.Sc. (*E.* 1930, *T.* 1936); Ernest Prebble (*E.* 1893, *T.* 1913); Albert Hedley Quick (*E.* 1904, *T.* 1928); Alexander Reid (*E.* 1895, *T.* 1908); Leslie St. Clare Rundlett (*E.* 1926, *T.* 1931); Mervyn Frederick Ryan, *C.B.E.* (*E.* 1910, *T.* 1922); *Sir* Leopold Halliday Savile, *K.C.B.* (*E.* 1895, *T.* 1914) (*Past-President*); Edward John Silcock (*E.* 1887, *T.* 1901); Freeman Gerald Sketch (*E.* 1919); *Lt.-Col.* Alexander Slater, M.B.E. (*E.* 1913, *T.* 1944); Robert Stirling (*E.* 1898); Gerald Swayne (*E.* 1901, *T.* 1933); Francis Thursfield, B.A. (*E.* 1895, *T.* 1909); Thomas William Townsend Tuckey, B.E. (*E.* 1890, *T.* 1900); James Scarlett Ascroft Walker (*E.* 1913, *T.* 1947); Arthur Cliffe Walsh (*E.* 1904, *T.* 1922); George Watson (*E.* 1894, *T.* 1906); Andrew Wilson (*E.* 1927); Guthlac Wilson, S.M., D.Sc. (*E.* 1928, *T.* 1938); (*Member of Council*); John Wood, *C.M.G.* (*E.* 1907, *T.* 1936) (*former Member of Council*); Charles Panton Farie Wright, M.C.E. (*E.* 1927).

Associate Members (67).—Silvanus Harold Arthur Abbott, B.Sc. (*E.* 1946); Alfred Bailey, B.Sc. (*E.* 1921); Cecil Edward Barnes, *D.S.O.*, *M.C.*, B.E. (*E.* 1948); Walter Kenneth Bartley (*E.* 1921); John Everard Barton (*E.* 1915); George Edward Bell, B.Sc. (*E.* 1915); Wilfrid John Benson, B.Sc. (*E.* 1936); Arthur John Bond (*E.* 1942); William MacGilvray Cargill (*E.* 1907); Alexis Amand Dallison Charles (*E.* 1900); Bertram Chatterton (*E.* 1894); Geoffrey Milne St. Barbe Connor, B.E. (*E.* 1934); Wellwood Cowan, *M.C.* (*E.* 1919); Hugh Stowell Cregeen (*E.* 1904); Charles Frederick Draper, B.A.I. (*E.* 1908); James Duff, B.Sc. (*E.* 1930); Bernard Arthur Duncan, B.Eng. (*E.* 1920); Oscar Geoffrey Duncan (*E.* 1939); Leonard William Elliott (*E.* 1946); Charles Julius Alfred Ellis (*E.* 1896); William Gemmel Fairweather, *O.B.E.*, B.Sc. (*E.* 1912); James Ferguson (*E.* 1912); Hugh Findlay, B.Sc. (*E.* 1931); Lawrence James Douglas Gibson, M.A., B.Sc. (*E.* 1905); George Edward Hall, B.E. (*E.* 1917); Charles Bernard Harrison (*E.* 1942); George Francis Xavier Hartigan, B.E. (*E.* 1917); Frederick William Hey (*E.* 1916); David Gay Hill, *M.B.E.* (*E.* 1901); William Geden Johnson (*E.* 1915); August Charles Koch (*E.* 1894); Wilfrid Drake Lancaster (*E.* 1911); Felix Lascelles, B.Sc. (*E.* 1909); Thomas Lunt (*E.* 1920); Ernest Francis McCourt (*E.* 1911); Kenneth Macpherson (*E.* 1945); Edwin McQueen (*E.* 1924); Thomas Patrick Murray, M.Sc. (*E.* 1939); John Haggie Patterson (*E.* 1908); Robert Walker Rennie Powrie, B.Sc. (*E.* 1925); John Alexander Rennie (*E.* 1913); David Cameron Robertson (*E.* 1907); Walter William Robert Roche (*E.* 1945); Samuel Romilly Roget, M.A. (*E.* 1902); Ernest Albert Salt (*E.* 1906); Edward Frank Sargeant (*E.* 1893); Cecil Scott (*E.* 1877); Robert Smith Scott (*E.* 1892); Thomas Reader Smith (*E.* 1888); Percy George Spary, B.Sc., B.Eng. (*E.* 1921); *Rev.* Roland Harry Streatfeild (*E.* 1907); Kuppuswami Subrahmanyan, B.E. (*E.* 1938); Ernest Arthur Tarrant (*E.* 1901); Ivan James Thatcher (*E.* 1907); Charles Thorp (*E.* 1936); Robert Ashfield Murugaser Thuraiappa (*E.* 1924); David John Tucker (*E.* 1952); James Clifford Wade (*E.* 1921); John Cameron Wallace, *M.C.*, M.A. (*E.* 1917); James Walmsley, B.A. (*E.* 1913); George Gordon Watson (*E.* 1932); William James Wells, B.Sc. (*E.* 1921); Henry Ambler Whitaker, M.Eng. (*E.* 1929); Arthur Edward Williams (*E.* 1892); Walter Hartley Wiswall (*E.* 1903); Trevor Moncrief Wright (*E.* 1926); Gordon Yeoman (*E.* 1908).

Associate (1).—Charlie Roland Woods, *M.B.E.* (*E.* 1938).

Students (8).—Geoffrey Knollys Briggs (*A.* 1950); John Norman Crow (*A.* 1951); Arthur Evans, B.Sc. (*A.* 1948); John Irvine Humphrey (*A.* 1947); Derek James MacKenzie (*A.* 1948); Derrick Dudley Rose (*A.* 1949); John Alan Scholes (*A.* 1949); Eddie Howard Woodward (*A.* 1947).

The following resignations have been received :—

Members (15).—Arthur Henry Barker, B.Sc., B.A. (*E.* 1925); *Sir* John Poland Bowen, *C.B.E.*, B.Sc. (*E.* 1912, *T.* 1925); Frederick Alexander Cowan, B.A., B.A.I. (*E.* 1921, *T.* 1930); Bernard Santo Crimp (*E.* 1917, *T.* 1927); Ernest Edward Finch (*E.* 1902, *T.* 1915); Harold Firth, *O.B.E.* (*E.* 1923, *T.* 1938); David Bird McLay, B.Sc. (*E.* 1910, *T.* 1925); Henry Edgar Morton (*E.* 1921); Charles Addison Neale, B.A., B.A.I. (*E.* 1922, *T.* 1946); George Charles Pearson, *O.B.E.* (*E.* 1935); Blair Ripley, *C.B.E.*, *D.S.O.* (*E.* 1918); Sidney George Stork, B.Sc. (*E.* 1920, *T.* 1935); George Hugh Swinburne (*E.* 1916, *T.* 1932); Frank Peake Tarratt (*E.* 1930); Richard Emrys Thomas (*E.* 1938).

Associate Members (69).—John Airey, B.Sc. (*E.* 1911); Robert Crafts Aldous (*E.* 1913); Arthur Aldred (*E.* 1913); Herbert Stanley Aldred (*E.* 1920); Peter Anthony Andrew (*E.* 1947); Alfred Bailey, *O.B.E.*, M.Sc. (*E.* 1915); William John Ball (*E.* 1908); Thomas William Barratt, *M.C.* (*E.* 1919); Frank Broomfield (*E.* 1907); William Michael Waddingham Brunyate, *M.C.*, M.A. (*E.* 1925); Arthur Havard Montriou Campion (*E.* 1915); Charles Alexander Chamberlin (*E.* 1912); John Harrison Clarke (*E.* 1915); Ernest Connell, B.E. (*E.* 1913); Harold Douglas Creedy, B.Sc. (*E.* 1911); Robert Crooks (*E.* 1928); Robert Curtis Cutting, B.Sc. (*E.* 1921); Eric Arthur Daley (*E.* 1947); Percy Dalton (*E.* 1917); David Tudor Davies (*E.* 1934); Thomas Charles Blagden Davies, B.Sc. (*E.* 1945); Charles Ernest Dickinson (*E.* 1920); Thomas George Royal Eagan, B.Sc. (*E.* 1924); William Eccles, M.Sc. (*E.* 1912); Gilbert Cecil Ninian Elliot (*E.* 1938); Peter James Theodore Fletcher, B.Sc. (*E.* 1946); James Garvie, B.Sc. (*E.* 1915); Lionel Cuthbert Hall, *M.C.* (*E.* 1909); Reginald Walter Leonard Allen Ham (*E.* 1920); Henry Alexander Hammick, *O.B.E.*, *M.C.*, M.A. (*E.* 1918); Fred Harrison, M.Sc. (*E.* 1913); Stanley St. George Harvey (*E.* 1910); Cyril Strachey Hawdon (*E.* 1912); William Houghton (*E.* 1914); Alexander Lindsay Houston (*E.* 1913); Henry Howe, B.A. (*E.* 1912); Frank Rupert Jemmett, M.A. (*E.* 1911); Howard Percy Byers Jones (*E.* 1913); Eric Kaye-Parry, B.A.I. (*E.* 1914); Stanley Darling Ker, B.Sc. (*E.* 1948); Thomas Henry Leader (*E.* 1915); Frederick William Lindup (*E.* 1928); John Ireland Long (*E.* 1916); William Barr McNab (*E.* 1909); William Franklin Marchinton (*E.* 1919); John Harland Marriott (*E.* 1917); Robert Okell, *M.C.*, B.Sc. (*E.* 1920); Edward Oscar Pearce, *O.B.E.* (*E.* 1911); Philip Septimus Pitt, M.A. (*E.* 1906); William Henry Power (*E.* 1919); William Reid (*E.* 1918); Clifford Ramiro Shaddick (*E.* 1912); Allan Tiefaine Simmons, B.Sc. (*E.* 1933); John Raymond Simpson, B.Sc. (*E.* 1943); William Harold Simpson (*E.* 1905); Nihal Singh (*E.* 1930); George Sommerville Smail, *M.C.*, B.Sc. (*E.* 1922); Alfred Travers Fairtlough Smith, *C.B.E.*, *M.C.*, B.Sc. (*E.* 1917); John Smith, *M.B.E.*, M.Eng. (*E.* 1920); *Prof.* Stanley Parker Smith, *C.B.E.*, D.Sc. (*E.* 1912); Ronald Fitzhardinge Speir (*E.* 1919); Gerald Frank Stacey (*E.* 1923); Albert William Stalker (*E.* 1920); Richard Stansfield (*E.* 1918); Bernard William Sutherns (*E.* 1928); Harry Willoughby Oddin Taylor, *C.I.E.*, *C.B.E.*, B.Sc. (*E.* 1921); Hugh Montgomery Thompson (*E.* 1937); Norman Lyell Wallis, B.Sc. (*E.* 1918); Travers Carey Wyatt, *O.B.E.*, M.A. (*E.* 1915).

Graduates (2).—Per Helge Ulstad, B.Sc. (*A.* 1952); Lawrence West, B.Sc. (*A.* 1952).

Students (64).—William Renwick Barbour, B.A. (*A.* 1949); Thomas Henry Barratt (*A.* 1949); Kenward Bennington, B.Sc. (*A.* 1950); Rowland William Bird (*A.* 1944); John Frederick Blatchford (*A.* 1950); Wallace Thomas Bray (*A.* 1950); Benjamin Michael Brewis (*A.* 1951); William Broadfoot (*A.* 1951); Alexander Brockie (*A.* 1946); John William Wright Campbell (*A.* 1949); Thomas Stewart Carson (*A.* 1949); David Derek Casstles (*A.* 1951); Raymond Charles Cook (*A.* 1950); Michael George Darvill (*A.* 1945); Stuart Ivor Davies (*A.* 1950); Arthur Edward Dudson (*A.* 1943); Ian Graham Toyne Duncan, B.Sc. (*A.* 1950); Nigel Kenneth Duncan (*A.* 1951); Michael John Field (*A.* 1946); Anthony Desmond Fitness (*A.* 1949); David Arthur Flint (*A.* 1950); Kulasekaram Ganesan (*A.* 1950); Morton Gould (*A.* 1946); Ronald Arthur Gull (*A.* 1949); Cedric Thomas Henthorn (*A.* 1944); Anthony Thomas Hope (*A.* 1950); Basil Horne (*A.* 1950); Peter Richard Hulme, B.A. (*A.* 1946); James Ormond Joss (*A.* 1946); Gerald Keats (*A.* 1947); William Rodney Stewart King (*A.* 1952); Philip Gordon Knight (*A.* 1946); John Derek Lawrence (*A.* 1949); John Viney Lefevre (*A.* 1944); Claude Walter Levinthal (*A.* 1943); Norman Webb Llewellyn (*A.* 1945); John McMurdo, *Jun.* (*A.* 1950); Eric Roy Manley (*A.* 1949); Michael Victor Manzoni (*A.* 1947); Brian Neville Sangwin Marson (*A.* 1947); Basil William Henry Martin (*A.* 1944); Kenneth William Mayne (*A.* 1948); Wilfred Habberley Meadows (*A.* 1947); Ronald Douglas Milne (*A.* 1950); David Reginald Mounsey (*A.* 1945); Hedley Arthur Oates (*A.* 1950); David John Oborne (*A.* 1946); Kieran Cathal O'Donnell (*A.* 1947); Edward Talbot Palmer (*A.* 1944); Stanley Harold Pugh (*A.* 1950); Robert Alban Courtenay Richards (*A.* 1951); Eric Andrew Richardson (*A.* 1950); Cyril Dyson Scoffield (*A.* 1947); Peter Simpson (*A.* 1947); James Mervyn Smallridge (*A.* 1947); David Whitson Smith (*A.* 1945); Richard Wilfred Woodger Smith (*A.* 1950); Neville Irwin Tarleton (*A.* 1949); James Livingstone Taylor (*A.* 1946); George Ernest Turner, B.A. (*A.* 1949); Ronald Douw Venter (*A.* 1948); Ian Sword Whitewright, B.A. (*A.* 1949); John Morris Williams (*A.* 1951); Alexander Nicol Young (*A.* 1951).

APPENDIX IV

BALANCE SHEET

31 March 1952 £		£ s. d.	£ s. d.
	INSTITUTION CAPITAL ACCOUNT		
414,759	*As per last Account*		414,758 16 10
	INSTITUTION BUILDING SINKING FUND		
	As per last Account	1,421 14 8	
	Add : Allocation for year to date	450 0 0	
	Interest on Investments and Income Tax refunded	54 0 0	
1,422			1,925 14 8
	REPAIRS AND RENEWALS RESERVE		
15,256	*As detailed on page 504*		9,582 15 2
	GENERAL REVENUE ACCOUNT SURPLUS		
	Balance at 31st March, 1952	22,827 2 9	
	Add : Surplus for the year to date, *page 505* . .	766 9 3	
22,827			23,593 12 0
454,264			449,860 18 8
	CREDITORS—		
	Sundry Creditors	19,493 16 9	
	War Memorial Fund	490 9 11	
15,898			19,984 6 8
	REVENUE IN SUSPENSE		
42,994	Proportion of subscriptions and examination fees received relating to the period after 31 March, 1953		47,490 5 10
513,156			517,335 11 2
	TRUST FUNDS		
	Capital Accounts	69,513 3 4	
	Unexpended Income—		
	Balance per last account . . 7,939 17 3		
	Add : Income received for the year to date 2,206 0 8		
	10,145 17 11		
	Less : Expenditure on Scholarships, Prizes, Lectures, etc. . 2,127 3 5		
75,828		8,018 14 6	77,531 17 10
	SEA ACTION COMMITTEE ACCOUNT—		
	Balance at 31st March, 1952	940 6 7	
	Add : Interest and other receipts for the year to date	48 16 4	
		989 2 11	
	Less loss on sale of investment	31 17 0	
940			957 5 11
589,924			£595,824 14 11

REPORT OF THE AUDITORS TO THE MEM

We have obtained all the information and explanations which to the best of our knowled kept by the Institution so far as appears from our examination of those books. We have ex of account. In our opinion and to the best of our information and according to the expla 31st March, 1953, and the general revenue account gives a true and fair view of the surplus

London, 8 May, 1953

L ENGINEERS

1ST MARCH, 1953

31 March 1952 £		£ s. d.	£ s. d.
	FREEHOLD PROPERTY—INSTITUTION BUILDING—		
375,768	*At cost, as per last Account*	..	375,767 16 10
	INSTITUTION INVESTMENTS (including those held in respect of Repairs and Renewals		
93,878	Reserve) at or under cost	..	85,878 7 5
	Market value, £74,607—(1952, £79,807)		
	INSTITUTION BUILDING SINKING FUND		
1,378	Investments at cost	1,871 14 8	
	Market Value, £1,715—(1952, £1,127)		
44	Cash awaiting investment	54 0 0	
			1,925 14 8
4,025	**DEBTORS**		3,760 2 3
38,063	**BALANCES AT BANKERS AND CASH IN HAND**		50,003 10 0
513,156			517,335 11 2
	TRUST FUND ASSETS—		
	Capital :—		
	Investments 69,494 10 6		
	Market value, £54,644— (1952, £51,764)		
	Balance at Bankers 18 12 10		
		69,513 3 4	
	Unexpended Income—		
	Investments 437 0 11		
	Market value, £328—(1952, £324)		
	Balance at Bankers 7,581 13 7		
		8,018 14 6	
75,823			77,531 17 10
	SEA ACTION COMMITTEE ACCOUNT—		
	£700 3% Savings Bonds 1955/65 at cost . . .	700 0 0	
	Balance at Bankers	257 5 11	
940			957 5 11
589,924			£595,824 14 11

E. GRAHAM CLARK, *Secretary*

E INSTITUTION OF CIVIL ENGINEERS.

ere necessary for the purposes of our audit. In our opinions proper books of account have been ve Balance Sheet and annexed general revenue account which are in agreement with the books s the said Balance Sheet gives a true and fair view of the state of the Institution's affairs at the ded on that date.

ALAN RAE SMITH
J. A. JOHNSTON } AUDITORS.

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RESERVES FOR REPAIRS AND RENEWALS TO STRUCTURE, FURNITURE, FITTINGS AND MACHINERY

1951–52 £		£ s. d.	£ s. d.
28,029	BALANCE, per last account		15,256 8
	Add CREDITS during the year—		
560	Interest on investments and Income Tax refunded		559 18
	Institution Revenue Account—		
2,500	Amount provided for the year, *page 505*		2,500 0
31,089			18,316 6
15,833	Less NET EXPENDITURE during the year		8,733 11
15,256	BALANCE carried forward, per Balance Sheet, *page 502*		9,582 15

PUBLICATIONS EXPENDITURE

	To EXPENDITURE during the year—	£ s. d.	
20,837	Journal, Proceedings, etc.	26,811 9 9	
1,972	"Chartered Civil Engineer"	2,348 19 9	
—	"Géotechnique"—Expenditure less Receipts	524 7 10	
913	Charters, By-laws and Lists of Members	1,165 17 0	
815	Engineering Abstracts	757 12 0	
6,339	Salaries and Pension Premiums	6,940 12 8	
831	Miscellaneous Publications	148 10 6	
323	Reporting and Sundries	423 15 5	
32,080		39,121 4 11	
44	Less "Géotechnique"—Receipts less Expenses	— — —	
32,036		39,121 4 11	
9,759	do Credits for Advertisements, Sales, Subscriptions, etc.	16,673 12 6	
22,277	As per General Revenue Account, *page 505*		22,447 12

RESEARCH EXPENDITURE

	To EXPENDITURE during the year—		
1,853	Salaries and Pension Premiums	977 13 10	
18	Travelling to Committees	13 9 11	
265	Printing of Sundry Reports	393 3 3	
6	Sundry Expenses	4 3 6	
2,142			1,388 10
469	Less Sales of Proceedings and Reports		453 12
1,673	As per General Revenue Account, *page 505*		934 17

GENERAL REVENUE ACCOUNT FOR THE YEAR ENDED 31st MARCH, 1953

1951–52 £	INCOME.	£ s. d.	£ s. d.
66,252	Subscriptions received applicable to the financial year 1952–53	..	68,375 11 2
10,007	Entrance Fees	..	7,836 7 0
250	Life Composition	..	125 0 0
	Interest, Dividends, etc.—		
	On Institution Investments	1,980 0 8	
	On Deposit Account less Interest paid	209 4 10	
	Income Tax recovered for the year 1951–52	436 17 9	
2,529			2,626 3 3
	Examination Fees for the April and October 1952		
8,614	Examinations	..	9,559 14 11
159	Higher National Certificates—receipts less expenses	..	193 8 5
274	Library Fund Donations—received during the year	1,882 3 2	
	Less amount carried forward	1,000 0 0	
			882 3 2
88,085	TOTAL INCOME	..	89,598 7 11

Deduct EXPENDITURE.

14,383	House and Establishment Charges	14,446 1 9	
	Repairs and Renewals Reserve—		
2,500	Amount provided for the year, *page 504*	2,500 0 0	
	Salaries and Wages (including staff pensions		
20,625	premiums)	21,409 15 5	
5,643	Stationery, Postage, etc.	4,794 11 8	
22,278	Publications—*see page 504*	22,447 12 5	
1,673	Research—*see page 504*	934 17 7	
3,842	Library	4,249 9 1	
465	Library Reorganization	581 8 4	
6,629	Examination Expenses	7,658 17 1	
	Grants and Contributions— £ s. d.		
—	Local Associations 4,150 1 9		
—	Overseas Advisory Committees 111 14 8		
—	Other Bodies 144 8 10		
4,226		4,406 5 3	
348	Annual Dinner	208 6 2	
933	Conversazione	893 19 7	
262	Legal and other Professional Charges	324 16 6	
444	Public Relations Committee Expenses	250 7 11	
784	Engineering Conferences	2,034 11 9	
910	Travelling Expenses to Committees	1,030 19 4	
250	Other Expenses	209 18 10	
450	Institution Building—Sinking Fund Allocation	450 0 0	
86,645	TOTAL EXPENDITURE		88,831 18 8
Surplus 1,440	Balance, being Surplus for the Year carried to Balance Sheet		£766 9 3

OBITUARY

PROFESSOR RAYMOND GEORGE HUBERT CLEMENTS, who died at Ilfracombe on the 8th March, 1953, at the age of 72, was born at Ashwell, Hertfordshire, on the 3rd June, 1880.

He was educated in Edinburgh and was a medallist in Engineering at the Heriot-Watt College.

He entered the Ordnance Survey Office in 1896 and was there until 1901 when he was appointed an assistant in the Public Works Department in Edinburgh, subsequently becoming chief engineering assistant.

From 1908 to 1920 he was deputy Borough Surveyor of Brighton, but in 1916 he formed a local company and served with the Royal Engineers in Europe until 1919, attaining the rank of Major, and was responsible for about 3,000 bridges in the area administered by the Army of the Rhine. He was awarded the Military Cross and was mentioned in dispatches several times.

He returned to Brighton and undertook additional duties as Housing Director to the County Borough Council, but in 1920, joined the Ministry of Transport as Divisional Roads Engineer responsible for the Eastern and Home Counties. In 1926 he set up in practice as a Consulting Civil Engineer on highways and bridges. In 1929 he was appointed to the first and only Chair of Highway Engineering at London University until his retirement in 1939. During the second World War he was Deputy Chief Engineer to the Ministry of Home Security, and later served in the Home Office.

In addition to submitting numerous contributions to various professional institutions, Professor Clements served on many committees set up by the High Courts, Road Research Board, Ministry of Transport, British Standards Institution, etc.

He was elected an Associate Member of the Institution in 1908, and was transferred to the class of Member in 1925. He was also a Fellow of the Imperial College of Science and Technology.

He leaves a widow and two sons ; the third son was killed in 1942 while serving with the Royal Air Force.

SIGVALD JOHANNESSON, D.Eng., who died on the 22nd February, 1953, at the age of 75, was born at Copenhagen on the 7th May, 1877.

He was educated at the University of Copenhagen, from where he graduated as a civil engineer in 1900.

For 3 years he was employed on various tunnelling works for the London County Council and the City and South London Railway. From 1903 until 1910 he was engaged in the building of the Pennsylvania Railway tunnels into New York. Between 1910 and 1920, on the staff of the Interborough

Rapid Transit Company of New York, he was engaged on the reconstruction of the Manhattan Elevated Railway, and for the following 3 years was with the Hudson and Manhattan Railway.

In 1924, he joined the New Jersey State Highway Department as Design Engineer, in which capacity he supervised the design of the Pulaski Highway, an elevated highway from Jersey City to Newark.

In 1919, he was awarded the James Laurie Prize of the American Society of Civil Engineers, and in 1932 the Annual Bridge Award by the American Institute of Steel Construction. An honorary degree of Doctor of Engineering was conferred upon him by the University of Copenhagen in April 1951.

Among the books of which he was author or co-author are "Highway Economics," "Shield and Compressed Air Tunneling," and "Manhattan Elevated Railway Improvements."

Mr Johannesson also originated a method of moving concrete pavements by means of compressed air, which in one case was used to move the pavement of 12 miles of highway.

He was elected a Member of the Institution in 1929, and was also a Member of the Danish Society of Civil Engineers, the American Society of Civil Engineers, the American Concrete Institute, and a committee member of the Highway Research Board, United States of America.

He is survived by his widow.

ARTHUR JOHN WHYTE McINTOSH, who died at Crawley, Sussex, on the 15th April, 1953, at the age of 53, was born on the 2nd December, 1899, at Dundee.

He was educated at Harris Academy, Dundee and, after service in the Black Watch and Royal Navy during the first World War, at the University of St Andrews.

In 1924 he graduated in civil and mechanical engineering and was appointed to the Water Engineer's Department of the Corporation of Dundee. Later he worked with the City Engineer of Cardiff and the Borough Engineer of Oldham, where he was concerned with the design and construction of sewage treatment works. Then, under the City Engineer of Carlisle, he was responsible for the design and construction of the Eden Bridge.

In 1933 he went to Aberdeen as Deputy to the City Engineer and remained there until 1948. During this period he was associated with large civil engineering works, and during the second World War took an active part in the organization of rescue and first-aid services.

He left Aberdeen to take an appointment as Chief Engineer to the Crawley Development Corporation, and since this date was responsible for the engineering development of the New Town of Crawley. In 1950 he took over additional work as Engineer to the Weir Wood Water Board, and these two posts gave him many opportunities of applying the results

of new techniques in civil engineering. The first prestressed concrete road in Great Britain was constructed under Mr McIntosh's direction, and he was also responsible for a prestressed concrete reservoir with a capacity of 250,000 gallons.

In addition to numerous contributions to technical journals on municipal engineering subjects, Mr McIntosh was co-Author of a Paper presented to the Institution describing the prestressed concrete road at Crawley.[1]

He served on several Government and Research Committees, particularly those dealing with street lighting, pedestrian crossings, and road construction.

He was elected an Associate Member of the Institution in December 1929, and transferred to the class of Member in October 1944. He was also a Member of the Institution of Mechanical Engineers, the Institution of Municipal Engineers, and the Royal Sanitary Institute.

He is survived by a widow and two daughters.

JOHN HALL RIDER, who died on the 23rd April, 1953, at the age of 89, was born at Bristol on the 30th January, 1864.

He began to study electricity and magnetism in 1880 at the Bristol Trades and Mining Schools, and for two successive years headed the list of students there. In 1883, he was apprenticed to Messrs Paterson & Cooper, and carried out lighting contracts in many parts of England and Norway for that firm. In 1887, he was appointed Electrical Engineer to Messrs Blakey, Emmett & Co. Ltd, of Halifax, and for 6 years designed and superintended the manufacture of their dynamos and electric light plant. He was appointed Borough Electrical Engineer to Bolton Corporation in 1893, and designed and built their electricity undertaking. In 1896, he obtained the post of Borough Electrical Engineer to Plymouth Corporation, and in this capacity he designed and superintended the construction of combined work for electric lighting and traction. In February 1901, he became Electrical Tramways Engineer to the London County Council, and carried out the conversion of the Council's tramways to electric traction.

In 1901, he visited the United States and Canada, on behalf of the L.C.C., to report on shallow underground tramways, and the subway between the Strand and Theobalds Road was a direct result of this visit. In 1906 and 1907, Mr Rider assisted in the preparation of electricity bulk-supply schemes promoted by the L.C.C., and was the principal engineering witness before Committees of the House of Commons.

He went to South Africa in 1910 to take up the appointment of Chief Electrical and Mechanical Engineer to the Central Mining and Investment Corporation Ltd. He returned to England 5 years later to take up a

[1] A. J. W. McIntosh and Jack Mercer, "Construction of a Prestressed Concrete Road at Crawley New Town." Proc. Instn Civ. Engrs, Part II, vol. 1, p. 220 (Feb. 1952).

partnership in the firm of Preece, Cardew & Snell, Consulting Engineers of Westminster. His first important work with this firm was the completion of the new harbour power station at Belfast. He also designed power stations at Nottingham, Norwich, Swansea, and (in conjunction with the late A. J. Fuller) that at Fulham. His last major work was the Kingston power station, opened in 1948 by His late Majesty King George VI.

Mr Rider's services were in great demand in the 1920's as an expert witness in arbitration proceedings connected with electricity undertakings.

Mr Rider was elected an Associate Member of the Institution in 1896, and transferred to full membership in 1902. He was a member of the Institution of Electrical Engineers, was elected in 1909 to the Council of that Institution, and became a Vice-President in the following year. He was also a Past-President of the Incorporated Municipal Electrical Association, which had been founded on his initiative in 1895. In addition, he served on Engineering Standards Committees, and contributed several Papers to the various Institutions of which he was a member.

He leaves a widow and one daughter.

CORRIGENDUM

Proceedings, Part I, May 1953—

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ANNUAL GENERAL MEETING

9 June, 1953

HENRY FRANCIS CRONIN, C.B.E., M.C., B.Sc.(Eng.),

President, in the Chair

The President, having moved, and the Meeting having agreed, that the Report of the Council, which had been available to members upon request to the Secretary, be taken as read, said that on first looking at the Report it appeared to be a very ordinary document. However, on looking through it again, one appreciated that it represented the considerable amount of work and great activities of the Institution.

The first item in the Report was the Loyal Address to Her Majesty the Queen on the occasion of her Coronation. The Institution was very proud that the Queen was its Patron.

With regard to the meetings, they had been very well attended indeed, some having been extremely full. The awards for Papers presented for discussion at Ordinary Meetings would not be available until the end of the Session but, for the Papers which had been printed (with written discussion) between January and December 1952, the awards were available and would later be read by the Secretary.

During the year there had been several conferences, the most important being that on Civil Engineering Problems in the Colonies, which was well attended but, of course, it appealed only to a limited number of people.

The Proceedings, which were now issued in three parts, had been a great success. The standard had been well maintained, and the number of subscribers to Parts II and III exceeded all expectations.

There were now eight engineering Divisions—during the year the Hydraulics Engineering Division having been formed.

During the past few months a great deal of work had been done in classifying the books in the Library under the Universal Decimal system. The work had nearly been completed.

In addition, there had been started a collection of postage stamps bearing the imprint of civil engineering works, and the Crown Agents for the Colonies had presented a very remarkable set of such stamps dealing with the Colonies, for which the Institution was very grateful. The exhibition would be shown in part in the Library.

It was one of the President's greatest pleasures in his term of office to visit, with the Secretary, the Local Associations. He had been fortunate in that he had been able to go to all the Associations in turn. He paid

tribute to the work which was done by their Chairmen, by their Committees and, above all, by their Honorary Secretaries. The various Local Associations had different characteristics, but they were all most enthusiastic and did a great deal of work to keep the Institution together and to uphold it in the provinces. During the year the Yorkshire Association formed a Hull and East Riding Branch, which had already held five meetings.

The Institution always remembered the Overseas Associations, especially those which were in difficulties because they were in countries which were not as peaceful or as settled as Britain.

The Victorian Association was also mentioned in the Report, and members would probably be interested to know that a branch of that Association was being formed in Tasmania.

The Joint Overseas Groups in Abadan and the Argentine had been encountering difficulties. The Abadan Group was in abeyance, but the Argentine Group had held several meetings. A joint Overseas Group was being formed in Hong Kong.

At the last Annual General Meeting there were no Graduates on the Roll of the Institution, and it was gratifying to note that there were now 1,517. The total number of Students at the 31st March, 1952, was 5,843. This year there were 5,025, but there were also the 1,517 Graduates, so that the total number of Students and Graduates was now 6,542 as against 5,843 Students the previous year. Evidently the Graduate class had saved a number of the Institution's young men from going out into the wilderness when they became of such an age that they could no longer remain Students.

The Students' Associations had been very active. The London Association held an opening meeting at which he was present, and four other meetings as well as a joint meeting with the Institutions of Mechanical and Electrical Engineers.

An award was offered in a competition for Papers from the various colleges in the London University. No mention of this was made in the Report because the competition had been held too late for it to be included. The winner of the competition was Mr J. G. Measor, of the City & Guilds College, for his Paper on " A Review of Site Consolidation and Drainage by Ground Water Lowering and Other Methods."

The Students throughout the country had done very well. The London Students had been awarded three Miller prizes, and there were also three Miller prizes for the Edinburgh and East of Scotland Association, two for the North-Western Association, one Student of which also received the James Forrest Medal; and the Northern Counties, the Glasgow and West of Scotland and the South-Western Association each had one Miller prizewinner.

The second competition for the Institution Medal and Premium (Local Associations) took place on 15th October. There were four Papers, one from Edinburgh and the East of Scotland, one from the Northern Counties,

one from Northern Ireland, and one from the North-Western. The successful Student was Mr F. G. Johnson, a Student of the North-Western Local Association. He had had the great pleasure of presenting the medal to Mr Johnson at a dinner held in Manchester.

During the year there had been a number of elections to the Roll. One which he ought to mention was the Honorary Membership of Mr D. C. Howe, who was the Minister of Trade and Commerce in Canada.

The election of Associate Members was not so high as last year, there having been a fall of about 160, but he had already drawn attention to the increase in the Graduates section.

The Institution always took a very great interest in the education of young engineers, and during the year that subject had received a lot of attention from the Council. Of the 914 candidates who applied for election, more than 77 per cent had attended full-time courses at universities or technical colleges, and he thought it was generally felt that that was the best way for young men to prepare for the Institution examinations.

The examinations had attracted a large number of candidates—more than 2,000. The Professional Interview, which had been started a few years ago, had been under review with the object of making it possible for some of the older men, who might not have drawings available, to get through the Professional Interview, provided that the drawings which they produced, which might have been done by somebody else, were connected with their work.

With regard to the education of engineers in general, the Presidents of the Institutions of Mechanical, Electrical, and Civil Engineers, had worked very closely together, and had twice seen the Minister of Education. The first time she was quite unable to tell them anything. However, at the second interview, the relations between the three Institutions and the Ministry of Education appeared to be very cordial and it seemed to him that the Minister, in particular, and the Ministry, were willing to listen to what the three Institutions had to say. A memorandum expressing the views of the three Councils was being sent to the Minister of Education.

In connexion with education, there had been during the year a Conference in London of EUSEC, comprising the engineering societies of Western Europe and the United States of America, the three Institutions acting as hosts. The Conference took the form of meetings and visits to works and educational establishments, and another had been arranged for 1954.

One very pleasant occurrence had taken place. It had happened just before his term of office had commenced, but he had had the pleasure of making the presentation. The President of the Institution and the President of the Royal Society had recommended a name for the James Alfred Ewing Medal. Last year the choice had been Professor J. F. Baker, of Cambridge, who received the medal for the great contribution which he had made to the science of engineering in the field of research.

The Public Relations Committee had been reconstituted and made smaller, and the results so far had been encouraging.

An activity of the Institution which did not appear in the Report was in connexion with Lord Waverley's Committee on Floods. The Institution had been asked at very short notice to prepare a Memorandum for the Committee. About 10 or 12 members had been called together and the Memorandum had been prepared and submitted.

The Rockefeller Foundation had paid the Institution a compliment a year or so ago by asking it to form a committee to deal with the bursaries which the Foundation was awarding to students for post-graduate study at various colleges in Great Britain. The committee had interviewed a number of candidates and had made certain awards.

With reference to the visit of the Past-President, Mr Quartermaine, and the Secretary, to the United States and Canada during the previous year, he understood that the visit had been by no means a holiday—it had been very hard work, but much had been done to cement the friendship between Great Britain and the United States and Canada.

A sad note was that the Institution had lost four Past-Presidents by death during the year—Sir David Anderson, Mr S. B. Donkin, Professor Sir Charles Inglis, and Sir Leopold Savile.

Mr J. T. Chester moved to amend the reference in the Report to the Malayan Association. He said that " The new Honorary Secretary has not yet been appointed " was not strictly correct and should be deleted. Also, the difficulty in holding meetings was confined to the Federation and not to Singapore. Six meetings were held in Singapore but none was held in the Federation.

On being formally seconded, the amendments were agreed to.

There being no questions, the President proposed that the Report and Accounts be received and approved, and this was passed.

The Secretary announced the following awards for Papers published with and without written discussion in the November and December 1951 Journals and the Proceedings for 1952.

(i) A Telford Premium to Professor W. T. Marshall, Ph.D., B.Sc. (Eng.), M.I.C.E., and Chun Nung Hoo, Ph.D., B.Sc., jointly, for their Paper No. 5824, " An Experimental Investigation of the Stresses in Angle Brackets."

(ii) A Crampton Prize to P. A. Scott, B.Sc., M.I.C.E., for his Paper No. 5844, " A 75-inch-diameter Water Main in Tunnel : A New Method of Tunnelling in London Clay."

(iii) Telford Premiums to E. S. Crump, C.I.E., for his Paper No. 5848, " A New Method of Gauging Stream Flow with Little Afflux by Means of a Submerged Weir of Triangular Profile."
Professor J. F. Baker, O.B.E., M.A., Sc.D., M.I.C.E., and J. W. Roderick, M.A., M.Sc., Ph.D., A.M.I.C.E., jointly, for their Paper No. 5838, " Tests on Full-Scale Portal Frames."

P. W. Rowe, Ph.D., A.M.I.C.E., for his Paper No. 5788, "Anchored Sheet-Pile Walls."

Z. S. Makowski, Dip. Ing., for the joint Paper No. 5887 by Professor A. J. S. Pippard and himself on "Experimental Analysis of Space Structures, with Particular Reference to Braced Domes; with a Note on Stresses in Supporting Ring-Girders" (special thanks of the Institution being accorded to Professor Pippard, Member of Council).

F. J. Samuely, B.Sc.(Eng.), A.M.I.C.E., and P. J. A. Ward, A.M.I.E.E., jointly, for their Paper No. 5867, "The Skylon."

[The special thanks of the Institution are also accorded to Mr J. A. Banks for his Paper on "Problems in the Design and Construction of Knockendon Dam." (As a Member of Council he is ineligible to receive an award.)]

Mr A. B. Henderson, on behalf of the Scrutineers of the ballot for the election of the Council for 1953–54, said that, owing to a clerical error, a small number of duplicate copies of the voting paper had been issued but that practically all of them had been accounted for. The Scrutineers were able to state that, notwithstanding the error, the result of the ballot was beyond doubt, and they reported the election of the Council as follows:—

THE INSTITUTION OF CIVIL ENGINEERS
COUNCIL 1953–1954

President

WILFRID PHILIP SHEPHERD-BARRON, M.C., T.D.

Vice-Presidents

David Mowat Watson, B.Sc.
William Kelly Wallace, C.B.E.
Harold John Frederick Gourley, M.Eng.
Sir Frederick Arthur Whitaker, K.B.C., M.Eng.

Other Members of Council

Sir (Arthur) Stanley Angwin, K.B.E., D.S.O., M.C., T.D., B.Sc. (Eng.).
Donald Dunmore Ash (*Colonies*).
Professor John Fleetwood Baker, O.B.E., M.A., Sc.D., D.Sc.
James Arthur Banks, O.B.E.
Stanley George Barrett (*Northern Counties*).
Graham Townsend Bennett, O.B.E., B.Sc.
Ronald James Cornish, M.Sc. (*North-Western*).

Edgar Algernon Cross, B.Sc. (*Canada*).
Roy Hartley Edwards (*S. Wales & Monmouthshire*).
Arthur Floyd, C.B.E., B.Sc.
Henry Foster (*Yorkshire*).
Richard William Foxlee, C.M.G., C.B.E. (*Colonies*)
Ralph Freeman, C.B.E., M.A.
Sir George Herbert Fretwell, K.B.E., C.B.
Harold John Boyer Harding, B.Sc. (Eng.).
Garner Llewellyn Hargreaves, B.Sc. (*Ceylon*).
Arthur Clifford Hartley, C.B.E., B.Sc.(Eng.).
Philip Haviland Haviland, O.B.E., B.Sc. (*N. & S. Rhodesia*).
Sir Claude (Cavendish) Inglis, C.I.E., M.A.I., F.R.S.
John Holmes Jellett, O.B.E., M.A.
James Patrick Leslie, B.Sc. (*South Africa*).
William Linn (*Glasgow & West of Scotland*).
Percival St. Lawrence Lloyd.
Robert McCreary, O.B.E., M.C., B.A., B.Sc. (*Northern Ireland*).
Edgar Ravenswood McKillop, C.M.G., O.B.E. (*New Zealand*).
Herbert John Baptista Manzoni, C.B.E.
Graham Morgan, B.Sc. (*Colonies*).
Reginald William Mountain, B.Sc. (Eng.).
Professor Alfred John Sutton Pippard, M.B.E., D.Sc.
Adrian Benson Porter.
Charles Arthur Risbridger, B.Sc. (Eng.) (*Midlands*).
George Edward Scott, O.B.E., V.D., M.Eng., B.Sc. (*South-Western*).
Alec Westley Skempton, D.Sc.
Percy Edward Sleight, M.Eng. (*Southern*).
Hubert Shirley Smith, O.B.E., B.Sc. (Eng.).
Marcus George Russell Smith, M.B.E., B.Sc.
Charles Bruce Townend, C.B.E., B.Sc.(Eng.).
John Harold Wallace Turner, B.Sc.
Thomas Haynes Upton, O.B.E., M.Sc., D.Eng.,M.C.E. (*Australia*).
James Paton Watson, C.B.E.
John Letham White, C.B.E., D.L., B.Sc.(*Edinburgh & E.of Scotland*).
Major-General Harold Williams, C.B., C.B.E. (*India & Pakistan*).
Robert Meredydd Wynne-Edwards, D.S.O., O.B.E., M.C., M.A.

And four Past-Presidents to be elected in November 1953.

Mr J. W. Moncur proposed—That a vote of thanks be accorded to the Scrutineers and that the ballot papers be destroyed.

The resolution was seconded by **Mr F. A. Partridge** and carried.

Mr Henderson, acknowledging the resolution on behalf of the Scrutineers, said that it might be of interest to members to know that 9,608 voting papers had been issued and 1,747 were returned.

Mr A. L. Little moved that Mr J. A. Johnston, Member, be reappointed Honorary Auditor for the current financial year; and that Sir Alan Rae Smith be reappointed the professional Auditor for the current financial year.

Mr Walter Reeve seconded the motion, which was carried unanimously.

Mr C. W. Knight moved—That the thanks of the meeting be accorded to Mr H. F. Cronin, President, for his conduct of the business as Chairman of the Meeting.

Mr C. E. Gayes seconded the motion, which was carried with acclamation.

The President, in acknowledging the resolution, said that it had been a great pleasure to occupy the Chair. It was the last time that he would appear in public as President, except for one or two minutes when he would hand over to his worthy successor, Mr Shepherd-Barron, in November.

The meeting then terminated.

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